IEEE Std 1491™-2005

IEEE Standards

1491™

IEEE Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications

IEEE Power Engineering Society

Sponsored by the
Stationary Battery Committee

IEEE

3 Park Avenue, New York, NY 10016-5997, USA

15 November 2005

Print: SH95345
PDF: SS95345

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IEEE Std 1491™-2005

IEEE Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications

Sponsor

Stationary Battery Committee
of the
IEEE Power Engineering Society

Approved 5 October 2005

American National Standards Institute

Approved 9 June 2005

IEEE-SA Standards Board

Abstract: Monitoring and measurement of battery parameters is an important element of maintaining a fully operational battery system. This guide presents and discusses measurable parameters of batteries used in stationary battery systems and the utilization of such observations. This guide does not give a listing of commercially available systems, but it does provide a means of establishing specifications for the desired parameters monitored.
Keywords: airflow, ambient temperature, automated battery monitoring, battery applications, battery current, battery environment, battery monitoring equipment, battery monitoring techniques, battery temperature, battery types, battery voltage, communications interfaces, connection resistance, cycles, grounding, ground fault detection, humidity, ripple current, safety, software, specific gravity

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Print: ISBN 0-7381-4734-6 SH95345
PDF: ISBN 0-7381-4735-4 SS95345

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Introduction

This introduction is not part of IEEE Std 1491-2005, IEEE Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications.

The monitoring of stationary batteries can be an important part of ongoing maintenance, testing, surveillance, and determination of the state of health of the battery system. Monitoring is becoming increasingly more significant with the decline of specialist crafts persons, cutbacks in maintenance personnel, the advent of unmanned battery locations, and sites that are difficult to access. This guide is intended to fulfill a need within the industry to provide background information, explain battery measurement parameters, and monitoring techniques.

This guide may be used separately, and when combined with other pertinent IEEE standards listed in Clause 2, it can provide a guide for total stationary battery maintenance.

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IEEE Guide for Selection and Use of Battery Monitoring Equipment in Stationary Application

1. Overview

This guide is divided into 11 clauses. Clause 1 provides the scope and purpose of this guide. Clause 0 lists references to other standards that are useful in applying this guide. Clause 3 provides definitions that are either not found in other standards or have been modified for use with this guide. Clause 4 reviews safety guidelines that are to be used with this guide. Clause 5 describes the two battery types used in stationary applications. Clause 6 provides an introduction to battery monitoring techniques and parameters. Clause 7 discusses the description, purpose, and limit of the various measurement parameters. Clause 8 establishes the various communication interfaces that a battery monitoring devices uses. Clause 9 discusses the electrical and physical operating environment to which the battery monitor may be subjected. Clause 10 provides typical technology found in battery monitoring. Clause 11 specifies considerations for different battery applications.

1.1 Scope

This guide discusses operational parameters that may be observed by battery monitoring equipment used in stationary applications, and the relative value of such observations. Although this guide does not give a listing of commercially available systems, it does provide a means for establishing specifications for the desired parameters to be monitored.

1.2 Purpose

Today's mission-critical environment has created a need for unmanned surveillance systems for stationary batteries. This guide will propose parameters for battery surveillance to achieve useful information for maintenance and replacement purposes. Because communications will play an issue with remote applications, a description of typical arrangements will provide additional insight.

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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.

Federal Communications Commission, Part 15 FCC Rules, Subpart J, Class B.[1]

IEEE Std 450™, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.[2, 3]

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

IEEE Std 946™, IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations.

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

IEEE Std 1184™, IEEE Guide for the Selection and Sizing of Batteries for Uninterruptible Power Systems.

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

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

IEEE Std 1189™, IEEE Guide for Selection of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.

NFPA 1, Uniform Fire Code™.[4]

NFPA 70, National Electric Code® (NEC®).[5]

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3. Definitions

For the purposes of this guide, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms*[6], should be referenced for terms not defined in this clause.

3.1 **battery monitoring equipment:** An unmanned fixed surveillance system for stationary batteries.

3.2 **Coup de Fouet**: Initial voltage drop and recovery of the battery under load.

3.3 **internal ohmic value:** Any value of resistance, conductance, or impedance derived from the relationships between changes in voltages and currents in a stationary battery under various conditions and used as an indicator of a battery's state of health.

3.4 **midpoint voltage:** The voltage between the positive or negative terminal of a battery and its physical midpoint.

3.5 **string:** Two or more cells connected in series to form a battery.

3.6 **thermal runaway:** A condition that is caused by a battery charging current that produces more internal heat than the battery can dissipate. This condition ultimately causes cell venting and premature failure.

4. Safety

Batteries are potentially dangerous, and proper precautions must be observed in handling and maintenance of batteries and monitoring system. Maintenance shall be done only by personnel knowledgeable of batteries and the monitoring system and trained in the safety precautions involved. Properly insulated tools and adequate personal protective equipment shall be used when working with batteries and the monitoring system.

The following personal protective equipment shall be available to personnel who perform battery maintenance work: goggles and face shields, acid-resistant gloves, protective aprons, portable or stationary water facilities for rinsing eye and skin in case of contact with electrolyte, class C fire extinguisher, acid or alkaline neutralizer, and adequately insulated tools.

Observe the following precautions:

a) Prohibit smoking and open flames, and avoid arcing in the immediate vicinity of the battery.

b) Avoid wearing metallic objects, such as jewelry.

c) Keep the top of battery clear of tools and other foreign objects.

d) Ensure unobstructed egress from the battery area.

e) Ensure that battery area and/or cabinet ventilation is operable.

f) Neutralize static buildup just before working on the battery by having personnel contact the nearest effectively grounded surface.

g) Do not remove battery vents.

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Only qualified personnel should perform maintenance on either the battery or the monitoring system. The use of proper safety and test equipment is of paramount importance. It is the ultimate responsibility of the individual technician to be aware of the potential hazards and appropriate safety precautions requirements of this type of installation. Follow the requirements of IEEE Std 450, IEEE Std 484, IEEE Std 1106, IEEE Std 1187, and IEEE Std 1188.[7]

The aforementioned guidelines are illustrative and do not cover every conceivable situation. Other guidelines, manufacturer recommendations, and federal, state, and county codes usually exist. Any personnel working on battery systems shall be aware of, and adhere to, all other applicable safety regulations.

4.1 Cautions

Always use caution when working on batteries, because the potential for lethal ac or dc voltages may exist at the battery terminals and/or between the battery and ground.

4.1.1 Opening battery string while string is connected to a load

It is recommended that a battery disconnect be used to isolate a battery from the system. If a battery disconnect is not provided, use extreme caution when removing the battery from the system. The entire string voltage will appear across any two open points when the string is disconnected from the system. Additionally, arcing may occur when the circuit is opened or closed. For example, if the terminals are opened at the individual cell level while the string is connected to a load, lethal voltages may be present across the open circuit that is created by removing one side of the connection.

4.1.2 Hazardous voltage path to ground and battery isolation from input power

A path to ground can be created through an uninterruptible power system (UPS) when the rectifier is connected to a transformer with a grounded winding. When the battery in a UPS system is not isolated from the ac input, a hazardous voltage may exist between the battery terminals and ground. Always test before touching. Check the voltage to ground (ac and dc) before working around the battery. If the voltage is other than anticipated, or is considered to be in an unsafe range, do not work on the battery until the situation is understood and/or corrected. Wear protective equipment suitable for the voltage.

4.1.3 Short-circuit potential

Do not make contact between cell/battery interconnections. Battery cells can deliver very high short-circuit current (sometimes in excess of 1000 A). A short circuit can result in injury or death. A single cell may produce thousands of amperes of short-circuit currents. Do not work alone.

4.2 Battery monitoring equipment

It is recommended that all components connected either directly or indirectly to the battery, including transformers, resistors, fusing, or positive temperature coefficient devices, be rated for the full battery voltage. The design should prevent high voltage or current at the monitor. It is a common manufacturing criterion, but users need to be aware that not all battery monitor manufacturers adhere to this criterion and full system voltage and high current potentials can exist in some monitors. Follow the battery monitor manufacturer's recommendation regarding grounding the monitor components. Users need to also be aware that conductive enclosures must always be grounded.

The battery monitor design should be such that a catastrophic failure to the monitor should not have any effect on the battery system, critical load, or personnel in the immediate area.

[7] Information on references can be found in Clause 2.

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The installation and operation manual for the battery monitoring system should be readily available to operating personnel. The installation of the monitor must be completed in accordance with the manufacturer's specifications. It is important that all sense leads be installed in a manner to prevent chaffing and possible shorting.

5. Battery types

Primarily two basic battery technologies serve stationary applications: lead-acid and nickel-cadmium. These batteries have design objectives specific to their application. Lead-acid and nickel-cadmium batteries are from very different technologies, each one possessing unique characteristics.

6. Benefits and limitations of automated battery monitoring

Automated battery monitoring systems perform many of the functions listed in 6.1 on an automatic, unattended basis. Measurements are automatically made with greater frequency, whereas the battery system remains online. The parameters are measured and recorded, and the analysis methods vary from manufacturer to manufacturer.

The advantages of automated systems are their ability to collect, store, report, and analyze data. A distinct advantage of the automatic system is its ability to monitor these parameters continuously, even during an unplanned outage.

The limitations of automated battery monitoring include physical battery maintenance tasks and visual inspections. Battery maintenance is essential and must be performed in accordance with well-documented maintenance practices.

6.1 Typical manual battery maintenance

Manual maintenance procedures are defined in other IEEE documents. Refer to IEEE Std 450, IEEE Std 1188, and IEEE Std 1106.

6.2 Typical automated battery monitoring

Measurements are automatically made while the battery system remains on line. The parameters are measured and recorded, and the analysis methods vary from manufacturer to manufacturer.

An advantage of automated systems is their ability to collect, store, report, and/or analyze data. A distinct advantage of the automatic system is its ability to monitor these parameters continuously, even during an unplanned outage. This information may allow the user to decrease the frequency of manual collection of some parameters of the battery.

7. Measurement parameters

The following parameters can be monitored periodically at set intervals or continuously by a battery monitoring system. These parameters can also be used in conjunction with battery manufacturer's published data to predict estimated run time and remaining battery life.

— **Voltage**: Cell, groups of cells, string, and battery terminal voltages.

— **Current**: Individual cell, string, float, charge, and discharge currents are measured and recorded.

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— **AC ripple current**: AC components of the string current are measured and recorded. In multistring installations, each string measurement is made and recorded.

— **Temperature**: Cell/battery and ambient temperatures are measured and recorded.

— **Interconnection resistance checks**: Intercell and battery connections are measured and recorded in microohms.

— **Internal ohmic measurement checks**: Each cell/battery is measured for ohmic values.

— **Specific gravity**: Each cell is measured for its specific gravity level.

— **Electrolyte levels**: Each cell is measured for its electrolyte level.

— **Coup de Fouet**: Initial voltage drop and recovery of the battery under load.

— **Discharge run-time analysis**: Some monitors may incorporate a run-time prediction during discharge.

— **Data analysis and reporting** : It is important that data are analyzed for trending over time and should be compared with baseline values. Some battery monitoring systems are capable of automatically collecting, trending, analyzing, and then reporting the results of the data collected. All systems should be capable of immediately reporting serious out-of-tolerance conditions.

— **Frequency**: The measurement intervals are dependent on the individual hardware selected and may be programmable. Automated systems do not negate the need for manual maintenance but can extend the interval between maintenance visits.

7.1 Float voltage

7.1.1 Description

Float voltage is the voltage applied to a cell/battery intended to maintain it in a fully charged condition during normal operation.

7.1.2 Purpose of monitoring

To identify and report out-of-range values that can impact performance potential and/or service life.

7.1.3 Indications and interpretations

Lower than specified voltages may result in loss of capacity, irreversible sulfation, accelerated grid corrosion, and premature end of life. Float voltage limits may need to be adjusted as a function of battery management algorithms such as temperature compensation, and intermittent charging. Limits on float voltages are defined by battery manufacturer specifications.

Higher than specified voltage may result in accelerated grid corrosion, excessive gassing, increased water loss [dry-out in valve-regulated lead acid (VRLA) batteries], thermal runaway, and premature end of life.

7.2 Equalizing voltage

7.2.1 Description

Equalizing voltage is a voltage above the normal float level that is temporarily applied to a cell/battery and is intended to correct inequalities in voltage and/or specific gravity among battery cells that may develop in

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service. This correction may be done manually or automatically and should be done according to the battery manufacturer's recommendations.

7.2.2 Purpose of monitoring

The purpose of monitoring equalizing voltage is to verify that its level and duration are correct and that the cell/battery has responded favorably to equalize charging.

7.2.3 Indications and interpretations

If the equalizing voltage is too high or applied for too long, it will result in increased battery temperature, excessive gassing rates, water consumption, grid corrosion, and premature end of life. Elevated voltages may potentially damage connected equipment.

If the equalizing voltage is too low, it will require an extended period to achieve the desired results. Also, if the equalizing voltage is applied for too short a period, it may fail to achieve the desired results.

Battery and connected equipment manufacturers' guidelines need to be consulted for the level and duration of equalizing charge.

7.3 Recharge voltage

7.3.1 Description

Recharging voltage is a voltage that is normally higher than float voltage, which is applied to a cell/battery to restore the energy removed during a discharge. Voltage applied should be the number of cells multiplied by the manufacturer's recommended recharging voltage per cell. In some applications, recharging and float voltage settings may be the same. Equalizing charge voltage and recharging voltage are sometimes used synonymously.

7.3.2 Purpose of monitoring

To identify and report when the recharging voltage level and duration are outside specified limits.

7.3.3 Indications and interpretations

High recharging voltage will result in a reduced recharge period but can increase battery temperature, gassing rates, water consumption, and grid corrosion and can cause premature end of life to the battery system and/or connected equipment in certain applications.

Low recharging voltage can result in extended recharge time or failure of the battery to reach a full state of charge.

7.4 Open-circuit voltage

7.4.1 Description

Open-circuit voltage is the voltage measured at the terminals of a cell or string after all charging sources and loads have been removed.

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7.4.2 Purpose of monitoring

The purpose of monitoring this parameter is to identify and report that the open-circuit voltage is within the manufacturer's parameters. The open-circuit voltage can be used for diagnostic purposes and/or to control the charging system.

7.4.3 Indications and interpretations

Excessively low voltage could indicate a shorted cell, low state of charge, or a reversed cell within the string.

The open-circuit voltage at a given temperature can assist in determining the state of charge.

Excessively high voltage could indicate that the electrolyte specific gravity is too high.

7.5 Discharge voltage

7.5.1 Description

Discharge voltage is the voltage measured across cell terminals and the battery terminals at any point in time during discharge. Battery manufacturers typically specify the total number of discharges available to a given depth of discharge under normal operating conditions.

7.5.2 Purpose of monitoring

Information concerning battery terminal and individual cell voltages during discharge, which is analyzed with respect to the discharge rate and time, is fundamental in determining the capacity of the battery, prediction of run time, analysis of individual cell performance, and intercell connection integrity. This voltage information may be used in conjunction with other information to provide an indication of the relative state of health of the cell or battery and predict the run time remaining.

7.5.3 Indications and interpretations

Excessively low cell or battery discharge voltage or the rate of voltage decay can indicate low battery capacity, battery deterioration, low state of charge, and/or high connection resistance. Some equipment has a low-voltage disconnect capability to protect the battery and/or the equipment.

7.6 Midpoint or partial string voltage

7.6.1 Description

Midpoint or partial string voltage is a monitoring technique consisting of measuring the float voltage of similar string segments and comparing these relative values. The accuracy of this method is inversely proportional to the size of the measured segments.

7.6.2 Purpose of monitoring

Comparing segment voltages can be a simple method of evaluating the voltage of groups of cells. It is effective in identifying shorted cells.

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7.6.3 Indications and interpretations

A wide spread in segment measurements indicates the need for more evaluation.

7.7 Cell/Battery dc current

7.7.1 Description

Current within a battery can be classified in three categories: discharge current, charge current, and float current. Cell current is the same as string current, unless a ground fault is present.

Discharge current is the flow of energy from the battery to the load.

Charge current delivers energy to the battery from the charger/rectifier after a discharge.

Float current is the current required to keep the battery at a full state of charge.

7.7.2 Purpose of monitoring

Current measurements can provide users with useful information related to the state of health of the battery. Current measurements can also be used to indicate the operation of the charger and/or the integrity of the cell connections.

7.7.3 Indications and interpretations

The magnitude of the discharge current compared with the capacity of the battery provides an indication of the run time.

With the constant voltage charger, the charge current should decrease to a stable value as the battery becomes charged.

The float current of a fully charged battery will depend on the temperature, voltage, and condition of the battery. A significant change in float current indicates a need for more investigation.

Fluctuations in the float current may indicate malfunctions in the charging or the battery system. The absence of float current may indicate charging system failure or an open circuit in the battery string.

A high float current may indicate failing cells present in the battery string, an elevated charger voltage setting, a ground fault, or a contaminated electrolyte. It is important to note that very small float currents are not easily read with typical measuring devices.

A rising trend of the float current may indicate potential thermal runaway, undercharged cells, charger system malfunction, or degradation of the battery.

7.8 Ripple voltage

See Annex C.

7.8.1 Description

The ripple voltage is the ac voltage component of the dc bus. It is important to note that not all chargers provide a level of ripple voltage that is readily measured and analyzed. It is typical for UPS systems to have

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a higher, measurable ripple component. Other applications such as telecommunications, switchgear, and engine starting will typically have lower ripple components than UPS.

7.8.2 Purpose of monitoring

To identify and report out-of-range values that could impact the performance of the battery and/or charging system.

7.8.3 Indications and interpretations

The normal level of ripple voltage for each system must be individually determined by initial and ongoing measured values. Consult the battery manufacturer for the upper limit of ripple voltage. Monitoring the exact value of this parameter is not as important as trending the value as the system ages. Escalating ripple voltages can cause higher than normal water usage in VLA cells and premature dry-out in VRLA cells. Higher than normal ripple voltages can often indicate a failure in the dc filter assembly or a defective semiconductor in the rectifier bridge.

7.9 Ripple current

7.9.1 Description

Ripple current is the ac current component of the charger output. It is important to note that not all chargers provide a level of ripple current that is readily measured and analyzed. Some UPS systems have a higher, measurable ripple component, but other applications such as telecommunications, switchgear, and engine starting typically will not.

7.9.2 Purpose of monitoring

To identify and report out-of-range values that could impact the performance of the battery and/or charging system.

7.9.3 Indications and interpretations

The normal level of ripple current for each system must be individually determined by initial and ongoing measured values. Monitoring the exact value of this parameter is not as important as trending the value as the system ages and comparing values between parallel strings on the same charging system.

7.10 Cell/Unit temperatures

7.10.1 Description

Cell/Unit temperature is the actual temperature of the cell as measured by a contact or noncontact temperature-measuring device. On VRLA batteries, it is common to measure the temperature at the negative post.

A single temperature reading may not be representative of the entire battery string. The more monitoring points used, the more comprehensive the picture of the entire battery string. When strings are operated in parallel, each string and tier should be monitored. If only one monitoring point is available, the highest anticipated temperature point should be selected as the monitored point.

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7.10.2 Purpose of monitoring

Temperature measurements are used to identify potential battery problems and can be used to control rectifier/charger output. A record of battery operating temperatures may be used for warranty validation.

Temperature readings can be used to optimize battery operation and life. However, expected ambient conditions must be taken into account to minimize the possibility of false alarms.

Temperature differential between ambient and cell temperature, and between cells within a string, can be monitored to ensure that it does not exceed the manufacturer's recommended maximum values. If this level is exceeded, it may indicate potential thermal runaway and the need for intervention.

Temperature readings are also necessary when trending and validating ohmic values.

7.10.3 Indications and interpretations

Abnormal temperatures affect the operation of the battery. Higher than normal temperature conditions lead to accelerated degradation of all lead-acid and nickel cadmium batteries. Temperature variations affect NiCd batteries less than lead-acid batteries. The impact of high battery temperature is critical and may lead to thermal runaway. Temperatures that are lower than those used in the sizing calculation may reduce the battery capacity to an unacceptable level.

7.11 Ambient temperature

7.11.1 Description

Ambient temperature refers to the temperature of the atmosphere where the batteries are installed, such as the battery compartment, room, building, hut, or cabinet.

7.11.2 Purpose of monitoring

Inside ambient temperature is relevant in determining the influence of temperature on the battery. However, it is not as good as direct battery temperatures. Care should be taken to place ambient temperature probes neither too close to nor on top of a battery. It is impossible to totally avoid the influence of heat from the battery, but attempts should be made to get the ambient temperature as opposed to the battery temperature.

7.11.3 Indications and interpretations

Battery temperature measurements are typically implemented in conjunction with ambient temperature measurements. Differences between ambient temperature and battery temperature can be critical, especially for VRLA batteries and may indicate ventilation problems. However, such differences may be from normal charge/discharge activities as well as from rapid fluctuations of the ambient temperature.

7.12 Cycles

7.12.1 Description

A cycle is defined as any battery discharge event followed by a recharge. The depth of discharge is the percent of ampere-hours removed as a function of the rated ampere-hour capacity of the battery.

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The number of cycles available from a given system is a function of the depth of discharge per cycle, the duration per cycle, temperature, and specific battery design. The battery design life and warranty requirements determine the importance of monitoring these cycle events.

7.12.2 Purpose of monitoring

The purpose of monitoring cycle information is to aid in determining the remaining battery cycles. It provides information for warranty claims and replacement decisions. Cycles for replacement purposes are based on number of cycles and depth of discharge as determined by the manufacturer.

7.12.3 Indications and interpretations

Battery manufacturers specify the total number of discharges available to a given depth of discharge under normal operating conditions. The monitor should be capable of storing and retaining this history over the life of the battery.

7.13 Cell/Battery ohmic measurements

7.13.1 Description

The internal ohmic value of a cell/unit consists of any value of resistance, conductance, or impedance derived from the relationships between changes in voltages and currents in a stationary battery under various conditions and used as an indicator of a battery's state of health.

In the absence of specific guidelines from the battery manufacturer and/or monitor manufacturers, changes in ohmic values in excess of a specified set value from the battery manufacturer at the same temperature and state of charge should be considered significant. In the absence of specific guidelines, more testing should be performed to determine the reliability of the battery system and the appropriate set value.

7.13.2 Purpose of monitoring

These measurements provide information about battery internal state of health and can be used for comparison between cells and for future reference and trending.

Significant changes in ohmic values typically indicate a significant change in the cell, which may be reflected in its performance. However, limited changes in the specific values obtained do not necessarily indicate that the cell is free of defect or deterioration.

7.13.3 Indications and interpretations

In the absence of specific guidelines from the battery manufacturer and/or monitor manufacturers, changes in ohmic values in excess of a specified value from the battery manufacturer at the same temperature and state of charge should be considered significant. In the absence of specific guidelines, more testing should be performed to determine the reliability of the battery system.

Cell replacement criteria are application specific. The timing of further action or replacement is dependent on the type of application and the load supplied.

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7.14 Specific gravity

7.14.1 Description

Specific gravity (SG) is a measurement of the density of the electrolyte. SG is dependent on the state of charge and temperature.

7.14.2 Purpose of monitoring

SG can be monitored to verify that it is within the design parameters of the battery. It can also be used to identify the failing cells.

7.14.3 Indications and interpretations

A deviation in excess of the manufacturer recommendation can indicate the need for more investigation. SG measurements may not be accurate when the battery is on charge after a discharge or after the addition of water.

7.15 Electrolyte level

7.15.1 Description

Electrolyte level is the measurement associated with the electrolyte fluid level in a battery cell. The fluid level in the battery cell needs to fall somewhere between the high and low marks found on the outside of a cell jar. This measurement is only applicable to flooded battery cells.

7.15.2 Purpose of monitoring

The purpose of this measurement is to ensure that the plates of the battery cell are fully submerged in electrolyte fluid at all times to prevent plate drying. A secondary reason for taking this measurement is to determine rate of change in electrolyte level as will be mentioned.

7.15.3 Indications and interpretations

Battery cell water requirements vary depending on the charge rate and charge voltage. It can also vary depending on the age of the battery cell. The rate of water consumption can be used as a rough guide to identify overcharging of a new battery cell or the potential need for replacement of an old battery cell. Short-term fluctuations in electrolyte level may also be caused by gas displacement during equalize charging.

The accuracy of the measurement of electrolyte level is meaningful only when the cell is at a full state of charge.

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7.16 Connection resistance

7.16.1 Description

Connection resistance is the resistance of the intercell connections measured between the connected posts so as to include both the resistance of the connector and the bolted connection.

7.16.2 Purpose of monitoring

The purpose of this measurement is to identify high resistance connections. It is very important to minimize the voltage drops in the connections to reduce power losses and to prevent catastrophic failure from overheating. The nominal connection resistance value is determined by the type and configuration of the interconnection hardware.

7.16.3 Indications and interpretations

Baseline resistance values for each type of connection should be established. Any subsequent resistance reading exceeding 20% of the baseline value or 5 μΩ, whichever is larger, or a lesser value specified by the manufacturer, should be identified and investigated further.

7.17 Ground fault detection

7.17.1 Description

Ground fault detection is defined as identification of unintentional current paths to ground from within the battery system. Examples of ground fault paths are electrolyte leaks, damaged cable insulation, dirt, moisture, and so on.

7.17.2 Purpose of monitoring

The purpose of this measurement is to ensure system integrity, performance, and safety by monitoring for unintentional current paths. Failure to detect ground faults can cause degradation of system reserve capacity, safety hazards, and if left unchecked, catastrophic failures.

7.17.3 Indications and interpretations

Refer to IEEE Std 946 for information regarding ground fault detection.

8. Communication interface

8.1 Description

Data collected or reported by the battery monitoring device must be communicated between the monitoring equipment and the user. Communication can be as simple as a contact closure or as sophisticated as a fully networked Web-based operation.

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This clause describes the interface between the battery monitor and the user. It can include local or remote communications to a host system/device designed to report constant status or event-based activity relevant to the monitored battery parameter.

The variety of communication architecture is dependent on site requirements, hardware configuration, operating systems philosophy, embedded systems, and cost considerations. Ease of use, standardization of protocol, hardware, and messages should be considered for the benefit of the battery monitor end user.

8.2 Local communications

The monitoring system is usually equipped with a local interface. Local communications will be dependent on site requirements.

8.3 Remote communications

Remote communications generally represents communication between the monitoring system and an off-site location. Remote communications will be dependent on site requirements.

8.4 Communication protocols and hardware interfaces

Both local and remote communications must occur with a protocol standard over a hardware interface. These may be proprietary standards or a combination of commonly accepted communication standards.

A full description of each method of communication is outside of the scope of this standard, but some frequently used communications options are listed in Annex A.

8.5 Security

8.5.1 Access control

There can be different levels of access, including read-only, report-only, or full programming and control. Security levels may be accomplished through such items as controlled software, password, dial-back capabilities, or proprietary network access. Security levels should be considered with user policies adopted to protect the most critical network elements.

8.5.2 Data security

Provisions for data security should be evaluated. It should include the fault tolerance or degree of redundancy of storage media, power supplies, and network components. Data backup to an off-site location should also be considered.

9. Operating environment

The operating environment is the electrical and physical operating environment to which the battery monitor may be subjected.

9.1 Electrical

The insulation strength of the battery monitoring system should be designed for the expected voltage to ground that is present within the battery system. The monitoring equipment must also be able to withstand

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and continue to operate in the presence of high common mode voltage in both ac and dc regions. The amplitude of the common mode voltage might reach a few hundred volts, and the frequency span of this voltage could be from hertz to megahertz.

9.2 Operating temperature

The typical operating range for an indoor application is +4 °C to +50 °C. For outdoor applications, the range can be from –40 °C to +65 °C.

9.3 Humidity

The typical operating humidity range is 0% to 85% noncondensing.

9.4 Enclosure

The typical indoor enclosure should conform to NEMA 1, NEMA 12, or NEMA 4X. The typical outdoor enclosure should conform to NEMA 12, NEMA 4X, and NEMA 3R.

9.5 Federal Communications Commission requirements

The battery monitoring system and associated equipment should conform to Part 15 FCC Rules, Subpart J, Class B or other applicable local requirements.

9.6 Grounding

The equipment grounding should be in accordance with the National Electrical Code® (NEC®) (NFPA 70) or other applicable codes.

NOTE—Utility-controlled areas, such as generating stations and substations, are exempt from the NEC.[8]

9.7 Corrosive and hostile environments

The battery monitor should be designed to operate in a corrosive atmosphere, which can be found in a typical battery room. Consideration should also be given to other corrosive or hostile environmental conditions such as salt water and acid rain.

10. Considerations when installing automatic monitoring systems

CAUTION

Personnel who are working on or around a battery should become familiar with the safety and cautionary details contained in Clause 4.

Today's advanced microprocessor-controlled battery monitoring systems have reached high levels of complexity, sophistication, and capability. As such, their installation is often a significant portion of the overall system cost as well as a large component in the proper startup and functioning of the completed system. Installation of battery monitoring sense and power leads can expose the installer to lethal battery

[8] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the guide.

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voltages and currents. Only a qualified installer should do installation with adherence to all applicable electrical and building codes. As many sites will be application specific, adherence to the manufacturer's installation guide and site-specific drawings is essential.

Connection hardware used on the battery should be stainless steel or lead-plated copper in the case of lead-acid batteries and nickel plated in the case of nickel cadmium batteries. The tab washer or ring lug is the preferred connection types where the application allows. See Figure 1 for correct installation of the tab washer and ring lug. Note the orientation of the stainless steel washer. Washers should be installed with the rounded shoulder facing the terminal post to prevent the sharp, stamped edge from cutting through the lead plating.

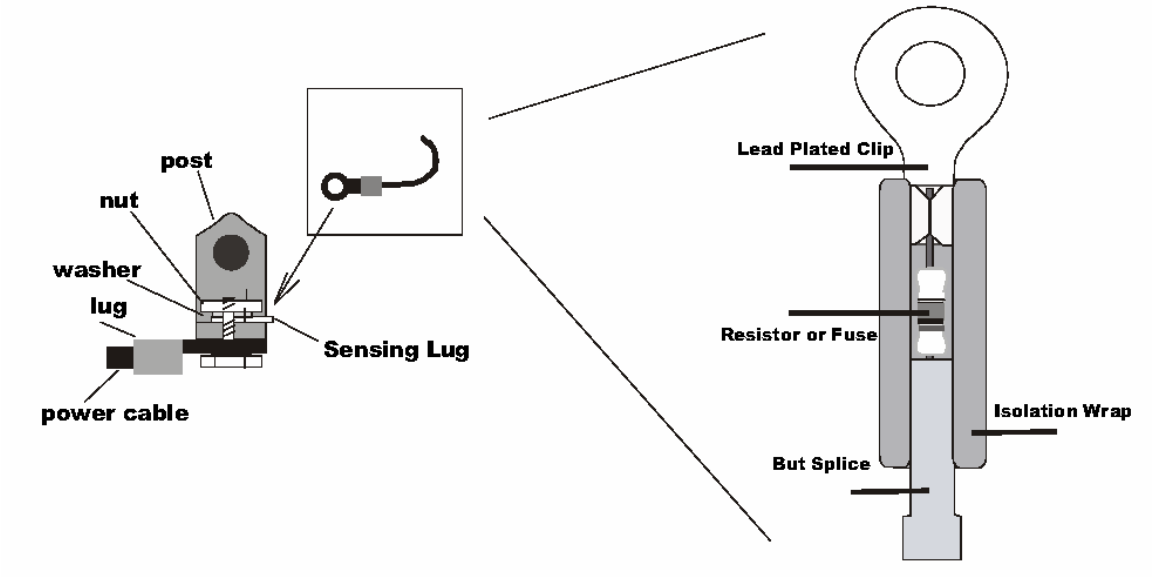


Figure 1—Typical sense lead connection (varies with manufacturer)

In retrofit applications, the c-clamp type of connector can be used if the application does not allow the use of a tab washer or ring lug. C-clamp leads must be installed at the same point on each successive intercell to maintain monitor accuracy (Figure 2). The "double nut" installation of either the ring or the tab terminal is not recommended as it negates the ability to properly torque the system during future maintenance inspections. Do not attach any hardware by drilling into the terminal post or intercell connector. Some installations, such as multicell mono-blocks with factory burned intercells, may require a combination of connector types. As noted, individual cells of multiple-cell mono-blocks should be individually monitored wherever possible.

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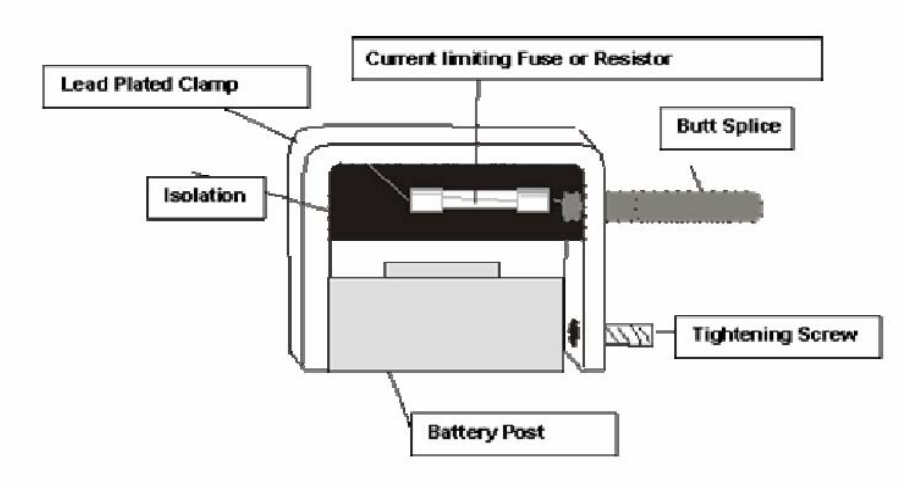


Figure 2—Typical clamp sense lead connection (varies with manufacturer)

All sense leads should have an in-line current limiting device that is rated to safely clear and contain the maximum overall string voltage at the maximum available short-circuit amperage rating of the battery. These should be installed as close as possible to the battery termination point. These current limiting devices include fuses, fusible links, resistors, optical isolators, and positive temperature coefficient devices. Extreme caution should be used when installing sense leads. On systems that use a removable fuse, remove the fuse when installing the sense leads to the battery terminals. On nonfused systems, verify that the other end of the sense lead is protected, remembering that on most applications, there is dangerous high-voltage and current potential between the battery terminals and the rack or cabinet. On vented lead-acid installations, wire installed between the terminal connector and the fusible link should be of acid-resistant construction.

WARNING

If the fuse, fusible link, resistor, or positive temperature coefficient device is rated at a lower voltage than the total battery string voltage, the device may explode under short-circuit conditions.

The typically large number of wires that need to be run with these types of systems necessitates that the installer perform all wiring in a workmanlike manner. It should adhere to all applicable safety guidelines, manufacturer recommendations, and federal, state, and county codes. It is recommended that in open rack installations, sense wire looms be placed in plastic cable troughs attached to the battery rack and plastic or metal conduit from the trough to the control module. Many manufacturers require that the length of the sense lead be uniform throughout the installation. In this application, it is important to install the coiled lengths of sense lead wire in such a manner so it does not interfere with future preventive or corrective maintenance. In VLA installations, the rack should not be drilled as this breaks the integrity of the acid-resistant surface coating and may affect the seismic rating of the rack.

In cabinet installations, the sense leads should be run in conduit from the battery cabinet to the control module. In no case should the installation of the sense leads interfere with normal preventive maintenance or cell replacement. Sense leads should be installed such that they do not touch the surface of the battery case wherever possible.

Do not run control wiring in conjunction with power cables. Control wiring should be run separately from power wiring and should be run perpendicular to power wiring whenever possible. Many manufacturers require shielded cables for their auxiliary sense leads. Where shielded cable is required, the shield should be grounded at the control module end only.

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Placement of the battery monitoring equipment and wiring should conform to local codes, be easily accessible, and be placed in the best available environment. There may be limits on the length of wire allowed between components, so verify maximum runs with the specific manufacturer.

The control module and associated equipment should be protected against power loss to the extent that the monitor backup time should exceed the battery run time of the monitored battery.

When changing out single cells or modules on a battery string, it is important to note that, depending on the type of monitor, there can be high potentials present even with the battery breaker open because many monitors have sense leads on the positive and negative posts and are grounded.

11. Monitoring considerations for different battery applications

11.1 Commercial data processing UPS

The UPS found in today's data centers is typically designed around operation in a climate-controlled environment where uptime reliability is the primary consideration.

Magnetic devices such as input isolation transformers and smoothing filter chokes are not always found in the commercial UPS. As a result, these devices cannot filter electrical noise that may be found on the dc bus. It may cause problems in monitoring low-level values.

11.1.1 Application

The data processing UPS typically requires a high-rate, short-duration battery plant. Most systems are rated at full load at the 15-minute rate to cutoff. These systems are typically characterized by 180 cell or 240 cell configurations resulting in very high bus voltages.

Systems backed by VLA battery plants typically also have generator capability and may use parallel strings backing an individual UPS for added reliability. These systems should be installed on open racks in an environmentally controlled room with specific attention paid to hydrogen venting and monitoring. Emergency eyewash and shower systems are generally installed.

Systems backed by VRLA battery plants are less likely to have generator backup, but they will often have multiple strings backing an individual UPS for added reliability. They are commonly installed in a small footprint cabinet next to the UPS on the computer room floor without forced air ventilation.

11.1.2 Operation

The primary operational consideration of the data processing UPS is 100% uptime. Although the system is typically designed for 15-minute run times at full load, few systems are running fully loaded giving them some additional runtime. Depending on the application, during this runtime window, the system is designed to switch to generator or allow an orderly shutdown.

Full-load capacity testing to cutoff is often performed on systems backed by VLA batteries but is seldom performed on VRLA systems. These systems are typically installed in manned sites with good environmental controls. Float voltage is tightly regulated, and equalize voltage levels are typically available, although generally used on VLA systems only. The UPS will generally have some limited battery monitoring capability and be designed to open the battery disconnect at a user-adjustable low-voltage cutoff point.

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11.2 Industrial (process control) UPS

The UPS for industrial process controls such as petrochemical, paper, steel, and other heavy industries is typically designed around operation in more hostile environments where a robust and reliable design are the primary considerations. These factors result in a UPS with a higher cost that uses established technologies.

11.2.1 Application

The battery plant backing an industrial UPS typically consists of 60 or 120 cells and will have a full-load backup time from 30 minutes to several hours. Enclosures are typically larger in footprint and more rugged in construction, often with a NEMA rating.

11.2.2 Industrial UPS

The battery in the Industrial UPS is frequently operational in a higher temperature and a potentially harsh environment. As such the importance of battery monitoring is amplified.

11.3 Telecommunications applications

Batteries employed for telecommunications have several unique installation locations, applications, operational, and maintenance features that can impact the battery monitoring requirements.

Most critical and large locations such as central offices (COs), mobile telephone switching offices (MTSOs), fiber hubs, and some cell sites have engine generator backup and are environmentally controlled. However, many cellular, repeater, and regeneration sites, although climate controlled, may not have heating, ventilation and air conditioning (HVAC) during utility power outages. Site temperature is usually elevated during discharge and initial recharge.

Many smaller locations such as cabinets and shelters may not have any HVAC facilities, can be dirty, and have limited access. In some locations, the battery vault or compartment may be completely enclosed and battery venting could present an explosive hazard.

11.3.1 Application

The reserve battery time is usually of long duration, typically three hours and up. The reserve time may be a legal requirement. Voltages can be 24 V or 48 V, either floating or grounded, and it may have either a negative or a positive ground. Constant voltage charging is usually employed, and the float voltage is usually tightly regulated with very low noise content.

With the exception of large switching centers, the field population of batteries is almost entirely of the VRLA type. Excess charging capacity is often available because of redundant charger configurations and engineered overcapacity. Switching centers usually have relatively constant loads, whereas radio sites have fluctuating loads. Typically, in critical applications, there are parallel/redundant battery strings.

In many cases, the battery may have external controls such as low-voltage disconnects, battery disconnects, high-voltage disconnects, and temperature compensation.

11.3.2 Operational

Telecommunication systems are typically of high reliability, with a minimum uptime of 99.99% is often required. There may be federally mandated issues. Discharge load testing may be difficult to perform because of site location, narrow maintenance windows, and the long test duration of a representative discharge time. In many cases, remote sites have high exposure to lightening and power aberrations.

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Although the batteries are sized for long duration discharge, short duration discharges are usually the case. Most locations are unmanned, and the physical size of the site can make maintenance and repair more difficult. Telecommunications circuits are usually readily available to facilitate remote monitoring.

11.4 Switchgear applications

In switchgear applications, the purpose of the battery is to permit continuous control of connected equipment such as circuit breakers, motor starters, and monitoring instrumentation. The battery is extremely important because the various dc devices can demand many times the capacity of the battery charger, which is sized to recharge and then maintain a float charge. The dc power in switchgear applications can be used for critical control of ac power distribution and generation. For example, failure of the dc power to the bearing lubrication pumps on large rotating equipment can result in catastrophic failure.

Switchgear control battery applications typically require output current levels that vary over a relatively long period of time. The battery operates on a float charge during steady state conditions. The battery charger powers relays, indicating lights, and peripheral devices during normal conditions. Instantaneous operation of the circuit breaker and switches require battery output current. Initially, this current may be relatively high for a short duration and then reduce for an extended period of time, followed by another high operating current demand. If the charger output is lost, these low-level currents are supplied by the battery for a specified period, typically eight hours. Instantaneous operation of the circuit breaker and switches requires relatively high battery current and may occur at any time during this period.

The battery capacity is load and user specific, but typically it is 300 Ah for transmission and 100 Ah for distribution. The nominal voltage is typically 48 V or 24 V. Often 120-cell lead-acid strings are used with a center tap to provide two 60-cell systems. Flooded lead-acid batteries are normally used, with flooded nickel cadmium employed for extreme temperature conditions. There is normally only one battery string, and it is typically not grounded. The environment can range from controlled indoors to uncontrolled outdoor cabinets.

Normally, there is not a load on the charger with the possible exception of some indicator lamps or relay coils. There is normally only one charger in the system, and this is typically rated at 12–16 A output. Reserve time can be 4 to 12 hours.

11.5 Engine-starting batteries application

Engine-starting batteries are frequently associated with critical, emergency, and life-safety electrical loads. Batteries used for this application have a relatively short duty cycle, typically 10 seconds or less, and a current output that may exceed several thousand amperes to initiate the rotation of a stationary engine. Most of the battery's life will be spent in a float charge condition.

11.5.1 Application

Reserve time is usually five full engine cranks, and voltages can be 12 V, 24 V, and 36 V dc. Applicable codes may require remote alarms for low dc voltage and loss of charge output. Environments range from controlled, inside applications to uncontrolled, outside applications.

11.5.2 Operational

Engine starting applications require very high reliability. Discharge load testing can typically be scheduled. Batteries may be colocated with the engine or remote.

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Annex A

(normative)

Communication options

A.1 Common communication protocols

TCP/IP
The transmission control protocol and the Internet protocol (TCP/IP) have become the most widely used protocol suites used in the world today. They are designed to facilitate the Internetworking of computer networks.

TCP/IP are designed to support and implement widely used gateway protocols such as the external gateway protocol (EGP), routing information protocol (RIP), and open shortest path first protocol (OSPF). In addition, TCP/IP contain application layer protocols such as TELNET and file transfer protocol (FTP).

The TCP/IP support of common gateway protocols and application protocols makes the use of TCP/IP inexpensive, quick, compatible, and flexible.

SNMP
The simple network management protocol (SNMP) is an outgrowth of TCP/IP communication needs on local area networks (LANs). The main implementation needs of fault detection, problem diagnosis, and report generation are met by SNMP.

SNMP uses the concept of management information base (MIB). A MIB consists of a set of variables and test points that all connected devices support. The use of MIB makes SNMP adept at accessing specific data the user requests. SNMP works by polling each device and reporting the status to a central processor.

An advantage to SNMP is the use of MIB allowing the user to monitor different variables on different devices. SNMP devices also allow for limited intelligence in the reporting devices as a simple “Yes” or “No” answer is sufficient when polled.

SNMP can cause a slow down in network traffic when many devices are connected. When monitoring several devices, the common management information protocol (CMIP) may be used as an alternative. This protocol uses a reporting versus polling approach resulting in less network traffic.

X.25
The X.25 standard was developed in 1974 for packet network interfacing. X.25 defines the procedures for the exchange of data between user devices (DTE) and a packet network node (DCE). The formal title for X.25 is the interface between data terminal equipment and data circuit terminating equipment for terminals operating in the packet mode on public data networks.

The major advantages to X.25 are its common use and high error accountability inherent to its flow control schemes. The major disadvantages to X.25 are the typical revision cycle of every four years, delay time, and the growing complexity of the functions being written into the standard.

Newer, less-complex technologies that provide higher throughput and less delay are currently available.

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Table A.1—Common hardware interface standards

		Communication					
Type	**Mode**	**Media**	**Distance**	**Noise immunity**	**Nodes**	**Advantage**	**Disadvantage**
RS-232	Serial	Common mode		High	2	Well established; standard on most computers	Only one transmission node possible; Transmission distance is short
RS-422	Serial	Differential		High	10	High noise immunity; long cable length for premises wiring	Two pairs required
RS-485	Serial	Twisted pair		Medium	32		
GPIB	Parallel	Parallel		High		High speed, up to 500 kB	Short transmission distance

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Annex B

(informative)

AC ripple voltage and current

B.1 Telecommunications power

The telephone industry developed the original specification of 30 mV maximum ripple at the terminal of the battery (measured peak-to-peak with an oscilloscope) when the battery had an 8 Ah capacity and at least four times the maximum rating of the battery charger. It was established to decrease the noise or hum on talking circuits. Rectifier manufacturers had to include chokes and filter capacitors in the design to meet this requirement. It led to the split bus power plant where the rectifier and the load were connected directly to the battery terminals. Using this type of connection, approximately 1.5 F of capacitance per 100 Ah was applied to the circuit. A typical 1680 Ah battery would yield 25 F of filtering.

B.2 Telecommunications electronic switching

When electronic switching was deployed in the telecommunications network, dc noise specifications became more stringent to avoid damage to the electronics (less than 1 A RMS per 100 Ah of battery capacity). Switch-mode rectifiers manufactured today have excellent ripple characteristics, and there is little ripple on the battery.

B.3 Utility power

Typically, the utility power company did not buy filtered rectifiers for generators and substations, because the connected equipment (e.g., switch-gear applications) could withstand the ripple of a normal rectifier connected to the battery. Today IEEE Std C37.90™-1989 specifies an allowable ripple of 5% for a 130 V (dc) system, that is, 6.5 V ripple.

B.4 Uninterruptible power systems

Some UPS's by their nature put a high ripple current into the battery. Some UPS's draw power from the battery in very high current, short duration pulses. It should not be confused with ripple current as it can be of sufficient magnitude and duration to count as a discharge cycle. With some UPS inverters tied to a battery, other ripple-sensitive equipment cannot be tied to the same battery. Although the battery ripple current maximums expressed in IEEE Std C37.90-1989 (>6 A per 100 Ah) will prevent battery heating even in UPS systems, it is uncertain what other effects ripple may have on battery life. Some UPS's use technology that has almost no ripple and does not draw power from the battery during normal operation.

B.5 Description

Ripple is the ac component of the system's charging voltage or current.

The amplitude of the ripple is primarily a function of charger design, charger output filtering, and the type and magnitude of load placed in parallel with the battery/charger system.

In a typical telecommunications system, the charger/rectifier is heavily filtered and the load is such that there may not be any significant ac ripple voltage or current to measure. Conversely, in typical UPS applications, users may expect larger ac ripple through the battery and possibly heating. Typically it occurs as a result of less filtering of the rectifier output voltage and lower impedance of the load.

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In the absence of the load, the charger/battery combination will not have the measurable voltage or current ripple unless the charger or battery is faulty.

B.6 Purpose of monitoring

To detect and indicate values of ac ripple voltage and current, which would indicate the need for corrective action within the system's electronics and which could also eventually lead to damage of the battery system from either heating or cycling.

B.7 Indications and interpretations

The limits typically imposed by battery manufacturers for VRLA batteries are approximately 0.5% RMS of the float voltage and 5 A per 100 Ah of rated capacity.

At the time of preparation of this guide, the adverse effects of the ripple current are not known other than the heating of the battery, which will result in a reduced life expectancy.

Some battery manufactures specify the maximum permissible ripple only in the form of the permissible ac ripple voltage. However, the user should use this limit with caution in that the resulting ac ripple current and resulting heating will be a function of the internal ohmic value of the battery—lower internal ohmic value resulting in higher ac ripple current, and higher impedance resulting in lower ac ripple current. The user should use this information with the understanding that although the battery may handle a certain degree of ac ripple voltage, the load may not. For instance, in telecommunication systems, the load will usually not tolerate a ripple voltage higher than 0.1%, whereas the battery might not be affected by a ripple voltage even five times greater.

The frequency of the ac ripple generated by the load/charger varies depending of the design of the charger/rectifier as well as the type of equipment being powered. In some UPS installations, the predominant ripple frequency will be a low multiple of 60 Hz; however, the spectrum might reach a few hundred kilohertz depending on system design. In telecommunication applications, even higher frequencies might be present. It is generally accepted that frequencies higher than 500 Hz will have less impact on the battery.

Although excessive ac ripple can negatively impact the battery service life, a small amount of ripple can exist with no measurable impact and can even be incorporated into the monitoring system as a "test" parameter. For example, when a small ac ripple voltage is applied to parallel strings of identical batteries, the same ac ripple current would be expected to flow through each string; if not, it may be an indication of an impending problem.

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Annex C

(normative)

Environment

C.1 Ambient temperature

Ambient temperature refers to the temperature inside the envelope where the batteries are contained such as the battery compartment, room, building, hut, or cabinet.

Ambient temperature is relevant in determining the influence of temperature on the battery. However, it is not as good as direct battery temperatures. Care should be taken to place ambient temperature probes neither too close to nor on top of a battery. It is impossible to totally avoid the influence of heat from the battery, but attempts should be made to get the ambient temperature opposed to the battery temperature.

Ambient temperature measurements are especially useful when compared with battery temperature. A differential (battery temperature minus ambient) of more than more than a few degrees Celsius could exist from the charge current flowing through them and the exothermic nature of the chemical reaction. Temperature differentials greater than this, or a continuously rising differential, could indicate thermal runaway. Under rapid air cooling, which is typically made possible with direct air conditioning, the batteries cool slower than the surrounding air because of their thermal mass. Therefore, it is possible for their temperature to be above that of the ambient.

Ambient temperature can also be used to help determine the effects on battery lifetime or to perform temperature compensation or other forms of charge current limiting when the battery temperature is not being measured.

The external air temperature refers to the temperature outside of the building, room, cabinet, or structure. In comparison with the inside ambient, the outside ambient temperature can tell us how well the envelope that contains our batteries is rejecting heat. For example, in a cabinet application, the inside temperature is greatly influenced by the outside temperature, and the differential between the two can indicate heat generated by batteries or equipment, as well as the efficacy of the cooling or ventilation system. If the outside ambient is measured outdoors, it should be measured in the shade to prevent erroneous readings caused by the direct influence of the sun.

External air temperature measurements may have little value in relation to the battery health and lifetime except for certain specialized applications. Battery and inside ambient temperatures are generally more valuable, in that priority order.

Ambient temperatures may need to be measured at more than one location (multiple probes) because of variations in temperature caused by solar loading, air circulation pockets, and stratification of the air from thermal flow. Because heat rises, inside ambient temperature sensors are generally best placed at mid-level in the envelope if only one sensor is to be used. When multiple sensors are used, any actions taken by the battery monitor based on temperature should usually be based on the highest temperature measured.

Battery monitors typically have a history log that can be used to store ambient temperature data. These data can be useful in determining the causes of battery failures and battery life. Typically the interval for data gathering is set by the user.

Just as with battery temperatures, alarm or action limits might be useful. A high ambient temperature may indicate the need to cool and/or ventilate the environment, or it may indicate a thermal runaway condition.

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High-temperature alarm limits may not be useful for uncontrolled environments because little can be done to cool beyond ventilation. However, high temperatures can initiate actions, such as temperature compensation. A low ambient temperature indicates that battery capacity is reduced. An example of how these data might be useful is that a low ambient may indicate the need for quicker dispatch of a portable generator to a remote site.

C.2 Toxic and explosive gas sensing

Several toxic and/or explosive gases related to lead-acid batteries exist. The most common of these gases are hydrogen (H_2), hydrogen sulfide (H_2S), and sulfur dioxide (SO_2). Specific to lead-antimony batteries, under abnormal conditions, there are concerns with arsine and stibine. Typically the only concern for nickel cadmium batteries is with hydrogen gas.

Sensors for the most common gases are widely available, using varying technologies, and have differing costs. The initial cost of the sensor should not be the only consideration when choosing a sensor. Maintenance costs are a big concern. The different technologies used have widely varying lifetimes (typically from one to seven years) and widely varying calibration intervals (typically from one month to one year).

Gas sensors can be used to send alarms and/or perform control functions, such as reducing or disconnecting charge current.

Multiple sensors may be used to find the gas at any level or in air pockets. However, adequate air circulation in the envelope will typically limit the need to just a single sensor. Just as with ambient temperature sensors, gas sensors should not be placed too close to the batteries to give the gasses leaving the batteries a chance to dissipate through diffusion and through any external ventilation openings. For example, a hydrogen sensor placed directly on top of a vented battery might always be in alarm state.

C.2.1 Hydrogen

Hydrogen is a normal byproduct of all aqueous batteries, including lead-acid and nickel-cadmium. In VLA batteries, it is constantly produced at a significant level under charge conditions. The higher the charge current, in turn the greater the gassing, which is typically from elevated temperatures and/or charging voltages. In general, VRLA batteries do not produce as much hydrogen gas as VLA batteries because of their recombinant mode. However, under extreme charge conditions, they have the potential to produce the same amount of hydrogen per cell ampere-hour as a VLA cell.

It is imperative to buy and maintain a reliable charging system, often with charge current control such as temperature compensation, to limit hydrogen gassing. See IEEE Std 1187 for more information on thermal runaway.

Hydrogen is explosive in concentrations from 4% to 74% in air. IEEE Std 484, IEEE Std 1187, and IEEE Std 1106 give the formulas for computing maximum hydrogen gas evolution from flooded lead-acid, VRLA, and nickel-cadmium cells. These standards also specify that the battery envelope be designed with a ventilation system to limit hydrogen buildup to 2% or less. Ventilation systems are often designed to keep this buildup to less than 1% or in some cases to less than 0.5%. Occupational Safety and Health Administration (OSHA) 29 CFR Part 1910.146, Appendix C,[9] recommends alarming and ventilation of confined spaces such as maintenance holes and buried vaults at 10% of the lower explosive limit for combustible gases (that is 0.4% for hydrogen) before human entry is allowed. Typically, confined spaces have been interpreted to be those that are fully or partially buried. In addition, some local codes may exceed national standards and may require explosive gas sensing. The monitoring can be performed with continuous monitors or with a portable monitor just before human entry.

[9] OSHA publications are available on the World Wide Web at http://www.osha.gov.

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Hydrogen gas sensors should be placed close to, or at the top of, the envelope because hydrogen is much lighter than air, and it will rise. Often, hydrogen gas sensors are commercially available as a combined sensor that will sense any combustible gas (e.g., hydrogen, methane, propane, etc.)

C.2.2 Hydrogen sulfide and sulfur dioxide

Hydrogen sulfide, commonly known as “rotten egg gas,” and sulfur dioxide are not normal byproducts of lead-acid batteries, and they are extremely toxic. See OSHA 29 CFR for exposure limits. They are only produced under extreme heat conditions, such as batteries that have been in extreme thermal runaway. A battery will be extremely hot and generate a lot of hydrogen before gassing any significant amounts of hydrogen sulfide or sulfur dioxide. For this reason, battery temperature and hydrogen gas sensors are often considered wiser investments than hydrogen sulfide or sulfur dioxide sensors.

Hydrogen sulfide is only slightly heavier than air, so any sensor should be located near mid-level of the envelope containing the batteries.

Sulfur dioxide is much heavier than air, so any sensor is best located near, or at the bottom of, the envelope containing the batteries.

C.3 Airflow

Sensing airflow is difficult in many environments in which batteries are placed because of the large area. Airflow is very important to batteries for two reasons: to keep the batteries cool and to prevent gas buildup. Continuous airflow is best for the same reasons. Because of the difficulties in measuring airflow, perhaps the easiest thing to do is to simply ensure that the optimum difference in unit temperatures is less than a few degrees Celsius.

Airflow sensors can be placed in HVAC ductwork or at ventilation intakes or exhausts to ensure airflow. If used, fans should be alarmed.

Ventilation systems should be designed in accordance with the guidelines given in IEEE Std 484 and IEEE Std 1187 and the NFPA 1: Uniform Fire Code, Section 64, 2003.

The climate, the temperature desired, the volume of the envelope, and the number of batteries (which will determine the maximum gassing rate) generally governs the proper amount of airflow. These parameters are generally given to a mechanical engineer to design the appropriate ventilation system.

C.4 Humidity

Humidity can affect batteries, and therefore, it is a parameter that can be useful to monitor. However, in many noncontrolled environments (e.g., cabinets), little can be done to alter the humidity, so it is basically useless to monitor it in these environments. Therefore, a decision on whether it is worthwhile to measure humidity should be made on a case-by-case basis.

Low humidity can cause premature dry-out of VRLA cells by permitting excessive water evaporation through the case. Low humidity can also lead to human-produced electrostatic discharge (ESD). ESD can be dangerous around the tops of vented/flooded lead-acid batteries where a high concentration of potentially explosive hydrogen is leaving the battery before diffusing through the air. Humidity above 40% will greatly reduce ESD occurrences and the magnitude of the charge released. At lower humidity levels, the frequency and magnitude of discharges increases exponentially.

Humidity levels above 65% can lead to excessive condensation on battery cases, which in combination with dust and/or leaked battery acid can lead to potentially dangerous shorting between cell/battery posts. High humidity levels can also accelerate the corrosion on battery posts, intercell connectors, and so on.

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The dangers of low or high humidity are generally not extreme; therefore, monitoring humidity strictly for the batteries may not be a necessary economical investment. However, the batteries are often supporting other equipment, which requires a certain humidity range. If humidity is being monitored and controlled for that equipment, the same measurements and controls will benefit the batteries.

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Annex D

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Sensors

A sensor is any device that gathers information that can be converted into readable form and evaluated or trended by either human or machine. Current limiting devices should protect sense leads.

D.1 Voltage sensors

The voltage sensor measures a difference in electrical potential between two points. This sensing is performed in several ways. The actual techniques used in determining potential difference are beyond the scope of this guide. It is sometimes necessary to scale higher voltages, with a voltage divider, to a level that can be read by a battery monitoring system.

D.2 Current sensors

The current sensor observes direction and magnitude of current in the battery circuit. This sensing is performed in several ways. The actual technique used in determining current flow is beyond the scope of this guide. The following discussion provides several ways in which the values determined are converted to a safe, readable level. In multiple string systems, monitoring on a per-string basis would be technically preferred to help isolate problems that may be unique to each string. With split-core or clamp-on type measuring devices, multiple cables can be measured individually and added for the total value. One or more cables in a multiple parallel cable group may be measured and the appropriate multiplication factor applied. This factor is valid only if all cable resistances are the same. Corroded or loose connections can impact the measurement.

D.2.1 Half-effect sensors

Split-core half-effect measurement devices do not require opening the battery circuit. Current flow measurement is obtained by sensing the magnetic field surrounding the conductor. Properly sized half-effect sensors can be clamped across the interconnection cables at any location in the string. Although half-effect sensors are less sensitive to the low frequencies commonly encountered, unless properly addressed, their readings can be upset by the high-frequency spectrum of current produced by some switching loads.

D.2.2 Magnetic field current devices

Magnetic field current measuring devices operate by using the magnitude of magnetic fields to calculate the time required to saturate the ferrite core. These devices are sensitive enough to detect the float current and, being nonlinear, will also cover a range of a few hundred amperes. At the lower end, they can also be used as a current transformer (CT) to measure the ac component of the current.

D.2.3 Current transformers

Measurements of ac components can be obtained with CTs widely used in ac applications. Measurements of ac currents are possible only when the battery is in a float condition. When the battery is being charged or discharged, the device is in a saturation condition and does not properly function.

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D.2.4 Shunt

A shunt must be installed in the current path to measure the current flow. Voltage drop across the shunt is proportional to the current. Shunt outputs are typically 50 mV or 100 mV at full rated current.

The shunts should be sized to carry the maximum rated current of the power source to which they are connected. The sensing leads from the shunt must be protected with properly rated current limiting devices.

D.3 Temperature sensors

A temperature sensor determines the temperature of a battery system or the surrounding ambient air. Temperature sensing is performed in several ways with various temperature-sensing devices. Common devices and methods include thermometers, thermisters, thermocouples, semiconductor, or infrared devices (thermography). Temperature-sensing devices can be analog or digital.

D.4 Gas sensors

Observation of residual hazardous gases associated with batteries is an important consideration in a battery monitoring architecture. Many types of sensors are used for gas detection. Some can detect multiple types of gases. Local building codes and company policy can also influence the type of gas monitoring used or the presence required in the monitoring system.

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Annex E

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Software

E.1 Operational software

The operational software is unique to each battery monitoring system and provides for the management and reporting of the monitoring system. The management could include, but is not limited to, the following issues:

a) Directly measured values, including analog and digital inputs.

b) Calculated or derived values, including the results of, or relationships between, one or more measured values.

c) Measurement intervals.

d) Date and time stamp of each measurement or event.

e) User-defined or preset thresholds for the measured, calculated, or derived value, including high, low, alarm, or realarm values.

f) Actions to be initiated when limits are exceeded. These can be manual or automatic.

g) Storage of the collected data.

h) Trending and analysis of data.

i) System outputs.

E.1.1 Alarms

Most battery monitoring systems report alarmed conditions and/or other systems status. This reporting may be local or remote.

Local status or alarm reporting may be at the front panel or to an audible or visual alarm system. The audible and visual alarms may be integral to the battery monitoring systems, or the battery monitoring system may simply activate external audible and visual alarms through relay contacts.

Local alarms may or may not be used, depending on location of the monitor and the site. Remote status and alarm reporting can occur through one or more of the different systems and protocols mentioned in 8.4 and in Annex A.

For example, a low voltage might trigger the on-board modem to dial a preset number or a high cell temperature might trigger a contact closure on the monitors. This contact might be connected to an alarm transmission device for reporting to a central location. An excessive float current might send an American Standards Code for Information Interchange (ASCII) text test message through the RS-232 port out through a pad and X.25 modem into a packet data network.

Eventually, this message would be analyzed by a network management system and sent to the appropriate personnel for analysis. The alarm or status reported is dependent on the capability of the battery monitor. The type of alarm/status transmission chosen depends not only on the monitor capability but also on the type of transmission available at that site.

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E.1.2 Reports

A report might contain the alarm history and measured values such as cell/unit voltage, string voltage, charging current, discharge current, float current, cell temperature, ambient temperature, cycles, or other parameters. Calculated or derived values including unfavorable trends, ampere-hours, watts, differential temperatures, predictive run times, interconnection resistances, recharge time, or other parameters could also be included.

E.2 Support software

Additional commercially available support software might be required to interface with the operational software to analyze and trend the data.

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