IET Standards

IET Standards Technical Briefing

Supported by:

centrica

Electrical Energy Storage: an introduction

CONTENTS

Acknowledgements

Lead technical author

EUR ING Graham Kenyon BEng(Hons) CEng MIET (G Kenyon Technology Ltd)

We would like to thank members of the IET Standards Technical Committee 3.3 Electrical Energy Storage Systems for their contribution to this publication.

Publication Information

Published by The Institution of Engineering and Technology, London, United Kingdom
The Institution of Engineering and Technology is registered as a Charity in England & Wales (no. 211014) and Scotland (no. SC038698).

The Institution of Engineering and Technology
Michael Faraday House
Six Hills Way, Stevenage
Herts, SG1 2AY, United Kingdom

www.theiet.org

It is the constant aim of the IET to improve the quality of our products and services. We should be grateful if anyone finding an inaccuracy or ambiguity while using this document would inform the IET standards development team at IETStandardsStaff@theiet.org or The IET, Six Hills Way, Stevenage SG1 2AY, UK.

SECTION 1

Introduction

Electrical energy storage systems (EESS) for electrical installations are becoming more prevalent.

EESS provide storage of electrical energy so that it can be used later. The approach is not new: EESS in the form of battery-backed uninterruptible power supplies (UPS) have been used for many years. EESS are starting to be used for other purposes. There are several reasons behind the increasing use of EESS:

(a) they make renewable energy more effective by ensuring that the energy that is generated by renewable sources is available when that energy source is not available. EESS can be used either to ensure that all energy generated can be used locally in addition to the grid supply or to provide total independence from the public supply.

(b) they make energy available during loss of the grid supply, enabling, for example:

- **(i)** 'controlled shutdown' of data centres and other computer and control systems to prevent corruption of stored data that would otherwise occur if the power was to be removed abruptly.
- **(ii)** electrical and electronic products and infrastructure to be used during power outages.

(c) they allow for grid support services, including fast frequency response, demand and supply management, network constraints, and power quality management. These services could be aggregated over a number of sites and are not necessarily located on generation sites.

(d) the falling cost of EESS, notably lithium ion batteries.

This Technical Briefing supports the forthcoming IET *Code of Practice for Electrical Energy Storage Systems*.

The scope of this Technical Briefing is limited to EESS technology that is based on electrochemical batteries and their associated charging control and protection systems. These are the predominant current and emerging technologies that are intended for use:

(a) with common low voltage (LV) supplies in use in the UK; and

(b) within electrical installations that are not part of the public electricity supply network.

SECTION 2

Reasons and benefits

2.1 Overview

Table 2.1 outlines the principal benefits, with respect to both embedded generation and demand and availability of the public supply.

Table 2.1 Principal benefits of energy storage solutions

Type of installation	Principal benefits of electrical energy storage	
	Relating to embedded generation/generation from renewables	**Relating to demand and availability of the public supply**
Dwellings	Availability of locally generated energy, when the energy source (daylight, wind) is not available. In rural locations, independence of the public supply may be possible. Embedded grid-demand support.	Low power loads could be supplied during extended periods of supply outage. This may include power for communications and data devices/device charging, media, LED lighting and heating control/ ignition for non-electric heating equipment. In rural or remote locations, independence of the public supply may be possible with local renewable generation. Reduce energy costs by charging off-peak where the load profile is high at peak demand periods (e.g. for homeworkers), subject to an appropriate tariff.
Commercial/ office premises	Availability of locally generated energy, when the energy source (daylight, wind, CHP) is not providing generation. Embedded grid-demand support.	Low power loads could be supplied during extended periods of supply outage. This may include power for communications and data devices/device charging, media, LED lighting and heating control/ ignition for non-electric heating equipment. Reduce energy costs by charging off-peak where the load profile is high at peak demand periods, subject to an appropriate tariff.

Type of installation	Principal benefits of electrical energy storage	
	Relating to embedded generation/generation from renewables	Relating to demand and availability of the public supply
Industrial premises key infrastructure	Optimise the use of any locally generated energy from renewable sources.	Reduce energy costs by charging off-peak where the load profile is high at peak demand periods, subject to an appropriate tariff. Provide power for safety or mission critical functionality when the public supply is lost, until local (prime mover) generation commences.
Transport etc. infrastructure	Local generation (e.g. by solar PV charging) provides independence from a fixed supply for low power loads (e.g. lighting for signage, electronic communications and surveillance etc.), permitting such equipment to be located at lower cost and/or on a temporary basis. However, to provide continuous operation independent of the generation source, there is a reliance on EESS.	

2.2 Operation states of energy storage systems

Table 2.2 outlines the EESS operation states. Certain types of EESS will not exhibit all of the operation states, in particular:

(a) UPS will only operate in four states:

- **(i)** charging (on-grid);
- **(ii)** discharging (on-grid);
- **(iii)** discharging (off-grid); and
- **(iv)** bypass.

(b) Grid-free systems, such as those used for stand-alone traffic signs with solar charging, will only operate in the following two states:

- **(i)** charging (off-grid); and
- **(ii)** discharging (off-grid).

Table 2.2 Examples of states of energy storage systems

State	Note	Loads	Energy storage batteries	Grid	Local generation
Charging (on-grid)	Not grid-free systems.	Powered from grid supply.	Charging.	Supplying power.	Supplying charging power (if available).
Charging (off-grid)	Not UPS.	Powered from local generation.	Charging.	Not supplying power or not connected.	Supplying power.

State	Note	Loads	Energy storage batteries	Grid	Local generation
Discharging (on-grid)	Not grid-free systems.	Powered from battery and/or grid supply.	Discharging.	Receiving power or not supplying power.	Supplying power (if available).
Discharging (off-grid)	-	Powered from battery and/or local generation.	Discharging.	Not supplying power or not connected.	Supplying power (if available).
Bypass	Not grid-free systems.	Powered from grid supply.	Charging, unless isolated for maintenance or because of a fault.	Supplying power.	Supplying charging power (if available).

Selecting systems

3.1 Introduction

For many practical installations, there is a choice of the following categories of EESS:

(a) packaged system: this is a complete EESS solution available as a commercial, off-the-shelf product. The system may have a.c. and/or d.c. interfaces and may be purpose built for use with a specific manufacturer's local generation system (for example, wind or solar PV system).

(b) discrete component system: this is an EESS composed of discrete components, for example, charging system and load controller, batteries, and isolation/switching devices. The system may have a.c. and/or d.c. interfaces.

(c) purpose-built UPS: this provides a.c. power via batteries in the event of input power being lost, typically for a single load or a specialist collection of loads.

(d) battery-backup system: this provides d.c. power in the event of the input power supply being lost, typically for a single load or a specialist collection of loads.

Table 3.1 Benefits and drawbacks of types of system

Type	Potential benefits	Potential drawbacks
Packaged EESS	'One-stop-shop' solution. Manufacturer takes responsibility for extensive type testing and ensures that the product can deliver its stated specification. Designer and installer involvement ensures that the product specification meets the needs and demands of the installation and that the install and commission is in accordance with the manufacturer's instructions. Operators and maintainers can follow manufacturer's recommended instructions. Can be suitable for profile shifting and grid-demand support.	Interface options, bespoke options and the range of system performance may be limited. Tied to 'manufacturer-recommended' or supplied replacement components.

Type	Potential benefits	Potential drawbacks
Discrete component EESS	Wider choice of interface options. Easier to make the installation bespoke to needs. Freedom to choose products from different manufacturers. Can be suitable for profile shifting and grid-demand support.	Greater reliance on the designer and installer of the system during the installation to correctly specify, source, install, test and commission. The design and commissioning stages would require more documentation. The designer and installer need to compile operation and maintenance information to ensure that the 'as-delivered' system can be safely operated and maintained. The designer and installer need to understand the user's load profile to properly configure and commission the system to deliver maximum efficiency.
UPS or battery backup system	Can be distributed throughout the electrical installation, closer to the point(s) of use or on selected circuits, to provide power in the event of a fault within other parts of the electrical installation, as well as loss of the grid supply.	Costly for smaller-scale commercial users and in dwellings. Generally independent of locally generated energy. Typically not suitable for grid-demand support or profile-shifting.

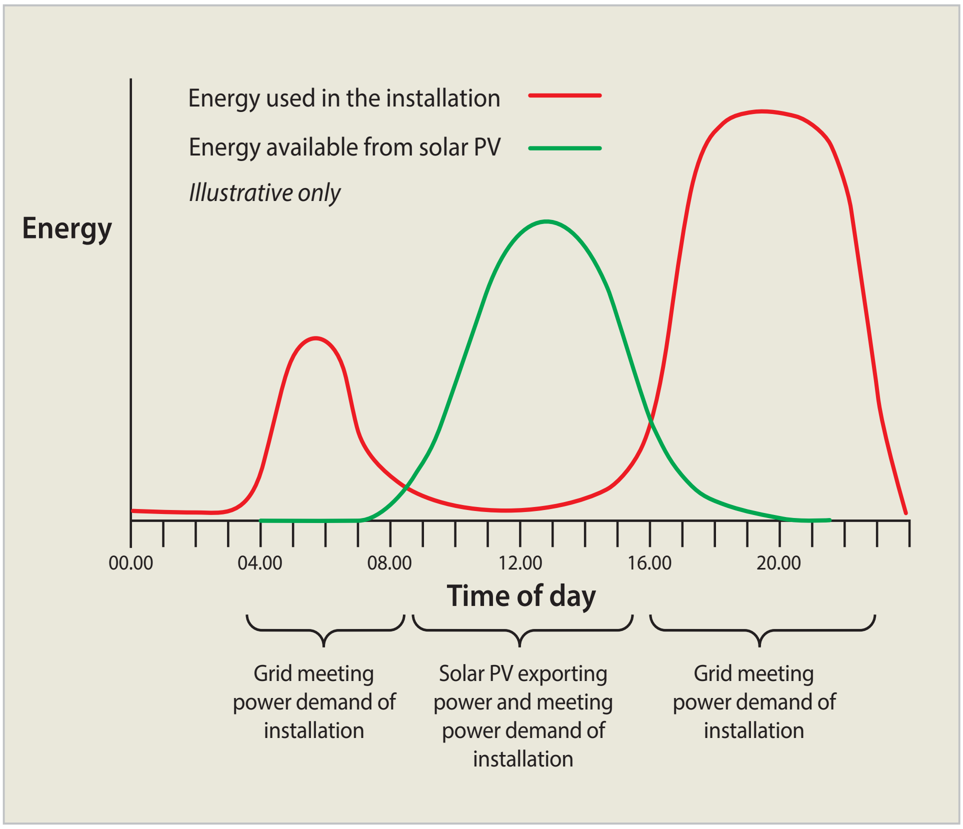
3.2 Purpose, load profile, charge and discharge cycles

In order to select an appropriate EESS it is essential to understand its purpose and benefits with respect to:

(a) the power/energy that will be used by the installation;
(b) variations in demand;
(c) renewable/local generation sources; and
(d) grid connection constraints.

Many systems will be used to modify the amount of energy consumed from the grid at certain times. Figure 3.1 shows what the energy demand and energy generation in an installation with solar PV might look like.

▼ **Figure 3.1** Illustration of energy demand/generation in an installation with solar PV; courtesy of G Kenyon Technology Ltd.

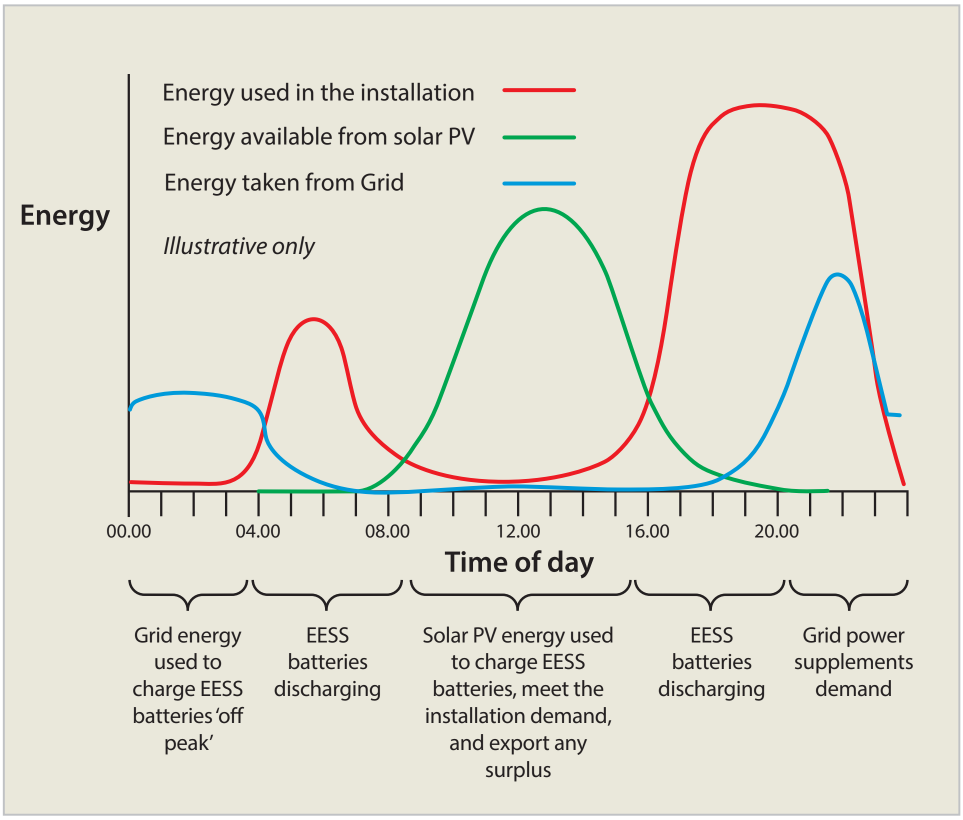


In Figure 3.2, an EESS has been employed to modify the energy used from the grid in the following ways:

(a) the energy generated by the solar PV system is used solely by the installation itself, which reduces the maximum demand from the grid ('peak lopping'), which may have the overall benefit of reducing grid demand at peak periods.

(b) energy from the grid is used at off-peak periods (perhaps at a lower energy rate) to charge the EESS batteries for later use before the solar PV system has started to generate power. Known as 'load profile shifting' or 'time shifting', this technology provides the benefit of cheaper power and the ability to use more from renewable sources of efficient energy, whilst enabling traditional grid generation technologies to be used at periods when the demand is less.

Figure 3.2 Illustration of how energy storage systems can bring cost benefits by modifying the load profile; courtesy of G Kenyon Technology Ltd.



Certain types of renewable generation have seasonal variations in their effectiveness. For example, during the UK's winter months, solar PV systems only generate a fraction of the power they generate during the summer months. In winter, there will therefore be more reliance of the EESS on time shifting grid power to off-peak periods to reduce energy costs, as the energy available from solar PV arrays may be insufficient to meet installation demands and/or fully charge batteries.

3.3 Main system components

Figure 3.3 illustrates in schematic form the components that may be found in an EESS. Not all systems will have all of the components but they are shown so that the concepts being discussed in this Technical Briefing can be illustrated.

In particular, the EESS controller may comprise several components in a system constructed from discrete components and include components and safety features, such as:

(a) double-pole switched isolation for the grid supply as in a typical solar PV installation complying with BS 7671;
(b) isolation transformers;
(c) d.c. to d.c. converters;
(d) a.c. to d.c. converters; and
(e) d.c. to a.c. inverters.

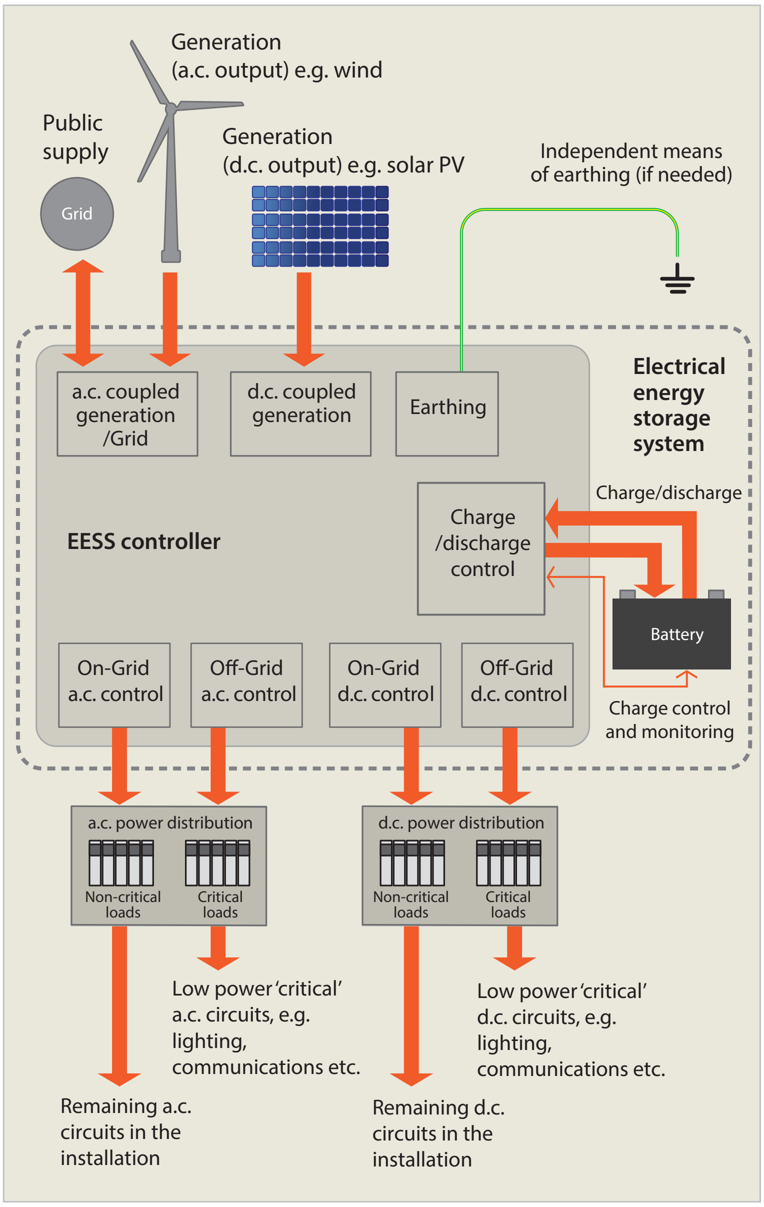
The overall efficiency of the EESS depends on many factors including the efficiency of the EESS controller. This is affected by power losses in operating the control electronics for charge, discharge and switching controls, and any losses associated with voltage transformation.

The EESS controller may be connected to sources of energy via a.c. coupling or d.c. coupling. Necessarily, the connection to the grid supply will be via a.c. coupling.

Coupling to other energy sources at standard voltages and frequencies defined in BS EN 50160 provides ready compatibility in the ratings of devices. However, the designer must still determine whether any electronic converters at the output of the energy source are compatible with a.c. to d.c. converters within the EESS controller. This is because the converters often operate using switched-mode design, and the waveforms from the switching devices may be incompatible.

d.c. coupling of energy sources, and indeed loads, may afford a lower-cost, more energy-efficient solution, even where d.c. to d.c. converters are used to change the d.c. voltage, as these are often more efficient than a.c. to d.c. and d.c. to a.c. converters. Whilst d.c. to d.c. converters also operate with switched mode circuitry, there are fewer compatibility problems due to the simpler way in which the d.c. output from the converter can be smoothed.

Figure 3.3 Overview of system components; courtesy of G Kenyon Technology Ltd.



3.4 The storage technology

The scope of this Technical Briefing is limited to electrochemical storage technologies, as this is the predominant technology that is currently available to meet the needs of EESS. Amongst other technologies, the following types of cell are currently popular for EESS:

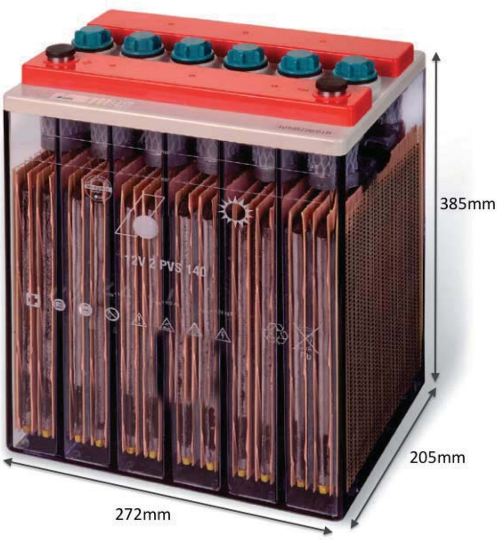
(a) lead-acid type batteries. These include acid-gel and valve-regulated lead-acid (VRLA) types.
(b) lithium-ion batteries.
(c) flow batteries.

This list is not exhaustive. Further information on batteries will be available in the IET *Code of Practice for Electrical Energy Storage Systems.*

Figure 3.4 Typical batteries

3.4a Lithium-ion battery courtesy LG

3.4b VLA battery courtesy BAE PVS



3.4c VRLA battery courtesy YUASA

These battery types are compared in Table 3.2 and other types of batteries are emerging as the result of research. Designers who are specifying installations should keep abreast of developments in storage technologies to ensure that the optimum battery types are selected.

The capacity of a battery is normally stated in ampere-hours (Ah). However, to understand how much energy is stored requires knowledge of the battery voltage. If we have a 100 Ah 12 V battery, this stores up to 1,200 Wh, or 1.2 kWh. Batteries may be connected in series or in parallel to increase the capacity, provided that this is supported by the charge management system to ensure that there are no overvoltages/overcurrents during charging.

Battery manufacturers typically recommend that the capacity of the battery is specified to be greater than the initial design capacity, by between 15 % and 50 %, depending on the battery technology, the maintenance replacement lifecycle, and the environmental conditions (chiefly temperature) in which the batteries will be used.

The key considerations when selecting the batteries are:

(a) capacity: check the battery capacity is adequate for the anticipated discharge requirement, whilst not too great so as to prevent complete charging. Incomplete charging can cause the battery to fail early and some battery types are unsuited to complete discharge.

(b) suitability: ensure that batteries are matched to the charge/discharge management components in the configuration in which they will operate.

(c) compatibility with environment: check that the batteries are suited to the environmental conditions and the facilities available to house the EESS (see Section 3.5), including the ability to safely install, maintain and decommission.

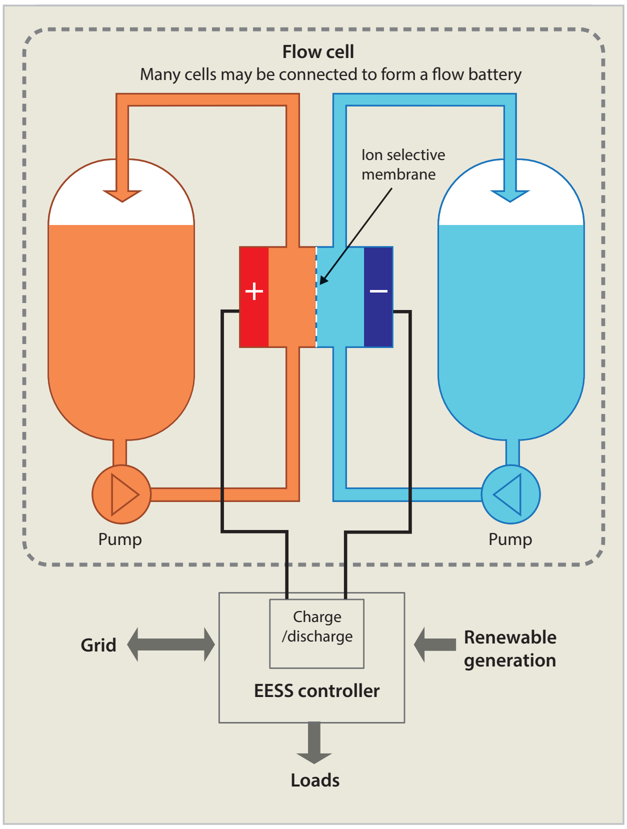
(d) disposal: batteries or their components will need to be disposed of at the end of their life, without damaging the environment, and in accordance with relevant legislation (Waste Batteries and Accumulators Regulations 2009).

Table 3.2 Comparison of lead-acid (VLA and VRLA), lithium-ion and flow batteries; courtesy of G Kenyon Technology Ltd.

Battery type	Notes	Advantages	Disadvantages
Vented lead-acid (VLA)	Oldest battery type, in commercial use for over 100 years. Operate from the action of lead and lead oxide electrodes, typically with sulphuric acid electrolyte.	Can deliver high currents. Easily recycled through existing channels.	Uses lead, which is harmful to the environment in disposal and potentially harmful to health for maintainers. Not suited to complete discharge, which may irreversibly damage the battery. Charges slowly. Releases hydrogen gas when charging, so fresh air ventilation is required. Electrolyte maintenance is required. The acid electrolyte is caustic.
VRLA	Sometimes known as 'sealed' batteries because they require no maintenance. Principally, there are two varieties: 'acid-gel' electrolyte or absorbent glass mat. Both operate on a similar electrochemical principal to VLA.	No maintenance required. Can deliver high currents. 'Deep cycle' versions are available that permit more complete discharge than VLA. Less susceptible to electrolyte leakage if broken. Easily recycled through existing channels.	Uses lead, which is harmful to the environment in disposal. Overcharging can damage the battery. In overcharge or fault conditions, certain VRLA batteries may produce hydrogen, and fresh air ventilation is therefore required.
Lithium-ion (Li-Ion)	A more recent technology, these batteries charge and discharge by the movement of lithium ions between the electrodes. Originally found popularity in the portable consumer and business electronic products market; advances in product safety and overall performance are now being driven by their use in the automotive electric vehicle market. Li-Ion batteries need protection systems to prevent thermal runaway.	Lighter, having between 2 and 5 times better storage capacity in terms of weight of the battery than lead-acid types. Between 10 and 20 times more charge-discharge cycles than lead-acid types, making them more suitable for frequent charge-discharge uses associated with load-profile shifting and domestic generation technologies such as solar PV. Operational life similar to VRLA.	Without protection systems, can be subject to thermal runaway. Not easily recyclable at present. Mechanical damage may lead to thermal runaway if not adequately protected against.

Battery type	Notes	Advantages	Disadvantages
Flow batteries	A very recent technology, where the battery operates somewhat similarly to a reversible fuel cell, or a large battery where the electrolyte is stored in tanks and pumped past electrodes, to increase storage capacity without increasing electrode dimensions. See Figure 3.5.	Increasing storage capacity does not mean a corresponding increase in short-circuit current. Thermal conditions in the cell are better managed as flowing electrolytes remove heat from the cell. Potentially longer service life. Can be tailored for very large EESS.	Requires energy to drive pumps. This is potentially far less significant for larger EESS, but may present inefficiencies for smaller EESS. *Note: Flow batteries therefore may be better suited to community EESS than individual dwellings.* Substances used in certain flow batteries, such as vanadium, may be harmful to the environment in disposal.

Figure 3.5 Key components of a flow battery system; courtesy of G Kenyon Technology Ltd.



3.5 Facilities

3.5.1 General

One of the key factors in deciding whether to install an EESS is whether there is a suitable and safe location for the system and its components. Considerations for facilities and the physical environment in which the EESS will be housed must be made, as discussed below.

3.5.2 Floor/wall loading

Battery sets of all types, in particular, can be heavy, and it is therefore important to assess where to mount equipment. This assessment will include consideration of the capability of the floors and/or walls to support it.

3.5.3 Temperature and ventilation

Current battery technologies suited for EESS perform at their optimum when charged, stored and discharged within a certain temperature band, although the actual temperature band depends on the battery technology and can vary between manufacturer and model. As an example, typical storage performance characteristics with respect to temperature for typical lead-acid battery types (VLA/VRLA) operating in standby power mode are illustrated in Figure 3.6.

The lifecycle of other technologies such as Li-Ion may be more complex, with the capacity over the life depending on:

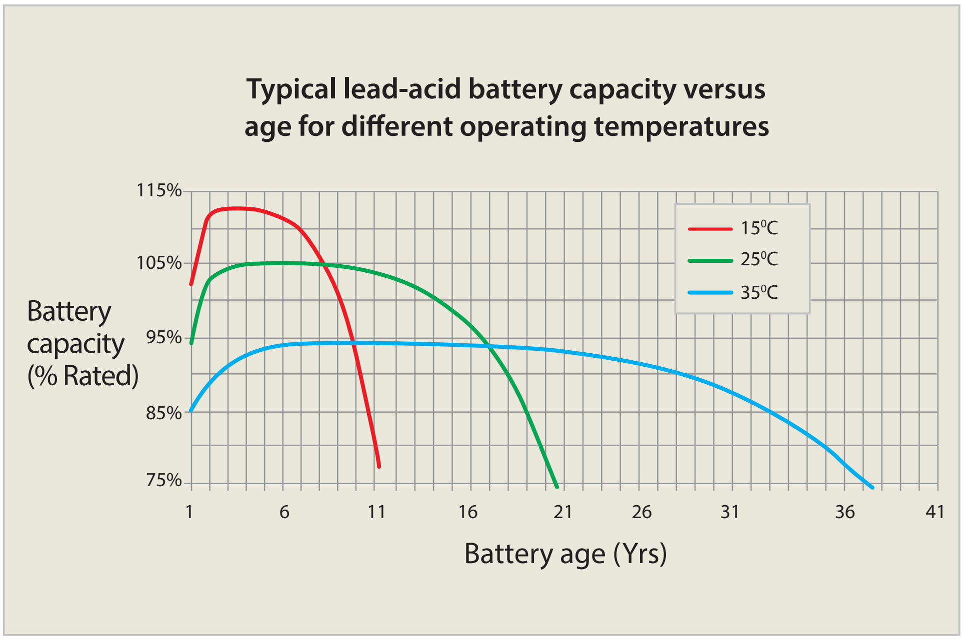
(a) the physical arrangement inside the battery;
(b) the particular electrolyte/electrode chemistry;
(c) depth of discharge;
(d) temperature during the charging period;
(e) temperature during the storage period;
(f) temperature during discharge; and
(g) the duration of the storage period.

Many Li-Ion cells designed for use in EESS contain in-built safety monitoring to prevent thermal runaway; it is also important for the charge/discharge management system to closely manage the charge/discharge cycles depending on temperature so that battery life can be optimised.

In the UK, the primary considerations are to help protect the battery from the extremes of winter and summer temperatures. Better performance can be obtained in locations where the temperature can be maintained within a limited range (dependent on type and manufacturer, but often 18 °C to 25 °C for lead-acid and Li-Ion types). With larger capacity energy storage installations, thermal management may prove cost-effective for improving performance and increasing time between maintenance replacements of batteries of certain technologies.

Certain battery technologies, such as lead-acid and VRLA types, require fresh air ventilation to prevent accumulation of hydrogen in explosive concentrations. Hydrogen may be produced during faults on the battery or charger. The air refresh rate should be calculated in line with the guidance of BS EN 50272 and any further information provided by manufacturers.

Figure 3.6 Storage performance life of typical lead-acid/VRLA batteries in standby mode; Paul de Montigny, Saskpower, via www.mpoweruk.com/life.htm



3.5.4 Access for maintainability

Certain properties of the location are important to ensuring that the energy storage equipment is safe to maintain, for example:

(a) workspace and access to equipment should be adequate to prevent electrical and other dangers during installation, maintenance and decommissioning.

(b) means of isolation and other protection should be clearly identifiable and readily accessible to the persons who need to access them.

(c) individual components that are heavy and require regular maintenance replacement (for example, certain batteries) should be located at a suitable height for lifting into and out of enclosures or housings. Ideally, there should be adequate room to manoeuvre the batteries without the maintainer having to twist as part of the removal or replacement.

(d) lighting should be adequate for installation and maintenance activities. There should be room to utilise temporary lighting regardless of whether lighting has been permanently installed, to enable work to be undertaken when power is disconnected.

3.5.5 Fire detection and suppression

The fire risk assessment for the premises should be consulted and, where necessary, revisited, when designing and installing an EESS. In addition to considering the effects of the EESS itself on the fire risk assessment, and any additional fire detection requirements, manufacturers and designers should be consulted to ensure that any fire suppression technologies in use in the location, or recommended by the fire risk assessment, are compatible with all of the EESS components.

The selection of inappropriate firefighting equipment or fire suppression system for a particular battery type may have devastating results.

3.5.6 Warnings and signs

Warning signs should be provided where necessary to:

(a) the general public and untrained staff, flagging that only trained and competent persons should maintain the system, and advising of the principal hazards of electric shock and any risks associated with the charging and battery technology (for example, corrosive chemicals or impeded ventilation).

(b) installers, maintainers, decommissioners and emergency services to flag any further hazards, such as the fact that there is stored energy (batteries) that cannot always be fully isolated and, where necessary, multiple means of isolation being clearly identifiable.

Signs used should comply with the Health and Safety (Safety Signs and Signals) Regulations and relevant standards such as BS EN ISO 7010.

Further signs may be required to indicate the means by which the installation (or parts of it) can be safely isolated and to indicate the voltage ratings of equipment and sub-assemblies where these are unexpectedly different from the normal supply voltage.

Electrical arrangements

4.1 Type

The low voltage grid supply in the UK operates at voltages and frequencies harmonized by BS EN 50160, i.e. at 230/400 V 50 Hz a.c. (or 230 V 50 Hz a.c. for three-wire three phase systems earthed at one of the phases).

The output voltage available from local generation depends on the technology used, and may vary, for example with the availability of solar or wind energy in the environment. Batteries by their nature operate within a defined d.c. voltage range during charge and discharge.

Table 4.1 Examples of arrangement of system types

Type of system	Possible system composition/arrangement
Stand-alone grid-free traffic sign, with solar array and LED light	Solar PV output is d.c. and is used to charge a battery through a charge controller. LED light operates from d.c., perhaps at SELV-compatible voltages. This can run directly from the battery voltage, so the controller may only further monitor for battery discharge depth. If the system is operating at SELV, it may have no requirement for a means of earthing.
Load profile shifting system only (e.g. for commercial or industrial premises)	The EESS is charged from the grid via an a.c. to d.c. converter and the charge-management system. During this period, loads are connected to the grid supply directly, and use the normal means of earthing. At a peak period, the grid supply may be removed from key loads via double-pole switching, and those loads supplied from the battery via an inverter. The inverter will require a suitable means of earthing where necessary to comply with BS 7671. An independent means of earthing may also be required for off-grid operation.
Grid-connected solar PV system with battery for load profile shifting	The system operates as a standard grid-connected solar PV system, but additionally has a storage battery and a charge controller to augment the solar PV element included in the system. The solar PV element may be a.c. or d.c. coupled. The switching and earthing arrangements comply with BS 7671, including the requirement to disconnect the system in the absence of the grid supply for safety. This type of system is further discussed in the IET's *Code of Practice for Grid Connected Solar Photovoltaic Systems*.

4.2 Principal hazards

The main hazards associated with an EESS as a whole, over and above those associated with any electrical installation, are:

(a) isolation of all electrical energy sources is not possible. Even with the wiring disconnected, individual battery cells or packs will be live at their terminals.

(b) there may be multiple points of isolation for circuits in the remainder of the electrical installation, particularly if the system is intended to operate off the grid. This presents a shock risk to those installing, maintaining and decommissioning the electrical installation as a whole, as well as the EESS in particular.

(c) energy storage devices can often supply significant short-circuit currents. Even at extra-low-voltage (ELV) this can present a serious risk of overheating and could lead to burns and/or fire.

(d) means of protection against electric shock may be exacerbated when the installation is operating off grid. This presents a hazard to anyone using the installation, so adequate earthing and circuit protection must be ensured.

(e) similarly to any EESS, electrical energy stored in batteries can be released abruptly if the battery is misused, particularly if they are stored or charged inappropriately or in inappropriate environmental conditions.

With careful design and suitable safety and protective measures hazardous situations can be avoided. This is demonstrated by the increasing proliferation of electric vehicles, which are currently operating safely on roads globally.

4.3 Off-grid operation

Where parts of the system are intended to operate off-grid or grid-free, and the electrical system requires an earth, for example, the supply arrangement is TT, TN-C-S or TN-S, then Section 551 of BS 7671 must be complied with, to ensure that adequate earthing is provided for the alternative source of supply where necessary to ensure safety, in the case that the normal supply earth is disconnected or subject to a fault.

Certain equipment within an installation may also require suitable earthing for functional purposes, including electromagnetic compatibility, and adequate earthing should be provided (see BS EN 50310 and Section 444 of BS 7671 for further details).

It is important to note that, in TN (earthed Neutral) systems, only one connection should be made between neutral and Earth in a system at any one time, and that the normal supply interface may therefore require multipole switching to ensure that there is no more than one simultaneous connection between neutral and Earth.

The requirements of ENA Engineering Recommendations G59 and G83 should be considered for systems intended for connection to the grid.

4.4 Electrical safety

4.4.1 Isolation and switching

Adequate isolation and switching is recommended to ensure that the installation can be safely maintained and de-energised under emergency conditions.

Adequate operation and maintenance instructions provided at the time of installation are key to ensuring that the system can be safely isolated. It is recommended that the operation and maintenance instructions have specific isolation procedures and emergency procedures included within them. Further instructions for users and emergency services can be provided on signs both at the origin of the electrical installation and at appropriate points on the EESS.

Such instructions and signs should address the target audience.

The requirements of ENA Engineering Recommendations G59 and G83 should be considered for systems intended for connection to the grid.

4.4.2 Circuit protection, earthing and bonding

Circuit protection, earthing and bonding should be provided in accordance with BS 7671. Where the EESS may operate as an off-grid supply (in BS 7671 this is called 'a switched alternative to the public supply') for any part(s) of the electrical installation, the requirements of Section 551 of BS 7671 should be considered very carefully to ensure that safety is not compromised under unusual conditions.

The model of 'fault of negligible impedance' used with LV systems does not always apply to ELV d.c. systems, and local heating at the point of fault can often result. Purely electronic supplies may incorporate various forms of electronic overcurrent and/or overvoltage protection; however, these should be used in conjunction with suitably selected overcurrent protective devices such as fuses or circuit breakers in case electronic protection fails. Further information is available in the IET Technical Briefing: *Practical considerations for d.c. installations*.

4.4.3 Safe working practices

Before starting work on any part of an EESS or an installation in which an EESS is installed, it is imperative to understand the arrangement of the installation and the location and function of the means of isolation and switching, in order to ensure that the part of the electrical installation on which work is required can be suitably isolated to prevent danger.

In addition to safe working practices for LV systems, particular care should be taken with ELV supplies, which provide currents in excess of 5 A, or short-circuit currents exceeding 10 A. Because of the reduced electric shock risk, there may be more of a temptation to work with SELV and PELV voltages live. However, this does not take into account the principal electrical safety hazard of high-current ELV supplies: that of the heating of conductors, and arcing/sparking, leading to fire.

The following are to be strongly recommended:

(a) avoid working live on energised high-current ELV systems;

(b) use insulated tools and adequately fused test equipment and test leads;

(c) remove metallic rings and other jewellery (which could otherwise become very hot if they inadvertently become a short-circuit in the system);

(d) consider the use of appropriate PPE, such as flame-retardant coveralls and associated eye or face protection, where there may be an increased risk of arcing and/or fire;

(e) consider risks of working with energised ELV systems when working at height as the risks are increased due to the potential for falls and falling objects; and

(f) avoid sources of ignition and naked flames in the vicinity of batteries, for example:

- **(i)** do not smoke in the area.
- **(ii)** avoid 'hot works' and the use of gas powered soldering irons.
- **(iii)** avoid tools that may cause sparks. The use of insulated tools and the removal of jewellery will prevent sparking and arcing.

4.4.4 Competence of installers and maintainers

The statutory requirements of the Electricity at Work Regulations 1989 apply, including the duty of Regulation 16 for persons to be competent to prevent danger and injury. Regulation 134.1.1 of BS 7671 requires:

"Good workmanship by skilled or instructed persons and proper materials shall be used in the erection of the electrical installation. The installation of electrical equipment shall take account of manufacturers' instructions."

Experience of electrotechnical professionals with EESS may be limited and it is recommended that anyone intending to engage a designer, supplier, installer or maintainer of EESS seeks to ascertain their previous experience with the technologies concerned.

4.4.5 Controls for use by the public or untrained personnel

The use of smart controls that will prevent users selecting states of operation that would be dangerous, damaging or costly should be considered.

4.4.6 Maintenance

Delivery of suitable operation and maintenance information, and effectively communicating the maintenance activities that impact upon safety and reliability of the installed system, will help to ensure that the installation remains safe throughout its intended life. Separate packages of information for the installation may be required for the person responsible for the premises and for those who will service, repair, inspect and test the installation; this is particularly true of dwellings.

The use of thermal imaging equipment during maintenance and safety inspection/testing can help to identify parts of the system that are not operating as intended.

References and related documents

Department of Energy and Climate Change URN 14D/221 *Implementing Electricity Market Reform (EMR)* June 2014

Department of Energy and Climate Change URN 15D/493 *Towards a Smart Energy System* 17 December 2015

IET *Code of Practice for Low and Extra Low Voltage Direct Current Power Distribution in Buildings*, 2015

IET Technical Briefing: *Practical considerations for d.c. installations*, 2016

IET *Code of Practice for Grid Connected Solar Photovoltaic Systems*, 2015

IET *Code of Practice for Electrical Energy Storage Systems*, forthcoming

BS 7430:2011+A1:2015. *Code of practice for protective earthing of electrical installations*

BS 7671:2008+A3:2015. *Requirements for Electrical Installations* (IET Wiring Regulations, 17th Edition)

BS EN 50272-1:2010. *Safety requirements for secondary batteries and battery installations. General safety information*

BS EN 50272-2:2001. *Safety requirements for secondary batteries and battery installations. Stationary batteries*

BS EN 50160:2010. *Voltage characteristics of electricity supplied by public electricity networks*

BS EN 62305-1:2011. *Protection against lightning. General principles*

BS EN 62305-2:2012. *Protection against lightning. Risk management*

BS EN 62305-3:2011. *Protection against lightning. Physical damage to structures and life hazard*

BS EN 62305-4:2011. *Protection against lightning. Electrical and electronic systems within structures*

BS EN ISO 7010:2012+A5:2015. *Graphical symbols – Safety colours and safety signs – Registered safety signs* (ISO 7010:2011)

ENA Engineering Recommendation G59 – Issue 3 (2015) – *Recommendations for the Connection Of Generating Plant to The Distribution Systems of Licensed Distribution Network Operators*

ENA Engineering Recommendation G83 – Issue 2 (2012) – *Recommendations for the Connection of Type Tested Small-scale Embedded Generators (Up to 16A per Phase)*

Waste Batteries and Accumulators Regulations 2009, SI 2009 No. 890

Electricity at Work Regulations 1989, SI 1989 No. 635

Health and Safety (Signs and Signals) Regulations 1996

SECTION 6

Terminology

6.1 Unfamiliar abbreviations

Abbreviations for SI Units, SI Derived Units, and related Non-SI Units, are not listed here due to their widespread use and standard application.

Term	Meaning
a.c.	Alternating current
BS	British Standard (UK National Standards)
d.c.	Direct current
EN	Euro-Norm (European Union Regional Standard)
EESS	Electrical energy storage system
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardisation
Li-Ion	Lithium Ion
SELV	Separated extra-low voltage
SI	Système Internationale (The International System of Units)
TN	Earthed neutral
UPS	Uninterruptible power supply
VLA	Vented lead-acid
VRLA	Valve regulated lead-acid

6.2 Specialist terms

Term	Meaning
Battery	A collection of energy storage cells as a package or system.
Battery backup system	A system that is equivalent to UPS for d.c. systems that can operate directly from the battery voltage in the absence of the normal power supply.
Extra-low voltage (ELV)	A voltage not exceeding 50 V a.c. or 120 V ripple-free a.c. whether between conductor or to Earth.
Grid	The public electricity distribution and transmission network.
Grid supply	The public electricity supply.
Grid-demand support	System being used to supplement means of grid generation at peak demand periods.

Term	Meaning
Load profile	Graphical representation of the load power demand within an installation over the course of a defined time period. The load profile varies throughout the day (daily load profile) and daily profiles vary with the seasons and public holidays.
Load profile shifting	Use of stored energy from an EESS to change the load profile seen by the grid, for example charging off peak and using the stored energy at times of peak demand.
Load shedding	Removing power from non-critical loads when there is insufficient power available from the grid.
Low voltage (LV)	Exceeding extra-low voltage but not exceeding 1,000 V a.c. to 1,500 V d.c. between conductors, or 600 V a.c. or 900 V d.c. between conductors and Earth.
Off grid	System not connected to a normal grid supply.
On grid	System connected to a normal grid supply.
Primary battery	Non-rechargeable battery.
Stationary battery	Battery that is not intended to be used in portable/hand-held devices and appliances.
Secondary battery	Rechargeable battery.
Separated extra-low voltage (SELV)	An ELV system that is electrically separated from Earth and from other systems in such a way that a single fault cannot give rise to electric shock.
Portable battery	Battery intended to be used in portable/hand-held devices.
Traction battery	Battery intended to be used to provide power to a source of traction, e.g. in an electric vehicle.

IET Standards

IET Standards Technical Briefing

Supported by:

centrica

Electrical Energy Storage: an introduction

Energy storage systems for electrical installations are becoming increasingly common. This Technical Briefing provides information on the selection of electrical energy storage systems, covering the principle benefits, electrical arrangements and key terminologies used.

The Technical Briefing supports the IET's Code of Practice for Electrical Energy Storage Systems and provides a good introduction to the subject of electrical energy storage for specifiers, designers and installers.

www.**theiet**.org/standards

IET Standards
Michael Faraday House
Six Hills Way
Stevenage
Hertfordshire
SG1 2AY