Contents

Introduction

This course is aimed at practicing electricians, electrical technicians and engineers with experience of electrical installations, and associated inspection and testing.

This training covers the installation of dedicated electrical energy storage systems (EESS) in accordance with the IET Code of Practice for Electrical Energy Storage Systems.

Candidates for this course will typically be updating their current competence or undertaking continuous professional development.

This candidate reference booklet accompanies a course on the application of the IET Code of Practice for Electrical Energy Storage Systems which will be referred to as EESS CoP.

The course is aimed mainly at installations associated with dwellings or small commercial locations. The purpose of this Booklet is to provide supplementary information to accompany the course. Some example exercises are included in section 5.

Learning Outcomes

There are seven knowledge-based learning outcomes and one performance-based learning outcome as follows:

You will:

- Know the key requirements for installation of electrical energy storage systems (EESS).
- Know and identify equipment, arrangements, and operating modes, of EESS
- Understand the preparation of design and installation of EESS
- Be able to prepare for the installation of EESS
- Be able to install EVCE
- Understand requirements for initial verification and handover of EESS
- Be able to conduct initial verification and handover of EESS

The training material is presented as a series of modules which should be worked through logically from Section 1 onwards. The material has been developed to support delivery in approved training centres and the course contains an element of practical work.

Assessment

The training manual contains a number of activities; these may take the form of multi-choice questions, or specific exercises. You'll also be encouraged to carry out your own research to supplement what you'll learn from the manual and on the course.

A very important part of the course is the assessment that will occur at the end. The assessment process will consist of an open book multi-choice assessment paper and practical assessments.

Course Material

This course material has been developed with the help and support of the following organisations and individuals:

- G Kenyon Technology
- Institute of Engineering and Technology (IET)
- NAPIT | training
- Gower College Swansea Coleg Gŵyr Abertawe Gower College Swansea

BPEC and MCS would like to express its sincere thanks for their help and support, and in particular for their permission to use images and extracts of learning material from their publications.

Whilst the basic design and installation principles of Electrical Energy Storage Systems are consistent, it's important for this course that you are aware of as many of the various manufacturers' products and methodologies as possible in order to provide a broader level of knowledge and understanding.

Supporting publications

The following publications also provide useful guidance

- BS 7671:2018 *Requirements for Electrical Installations. IET Wiring Regulations 18th Edition* or current version
- IET *Code of Practice for Electrical Energy Storage Systems*, 1st Edition 2017 or current version
- IET *On-Site Guide*, 7th Edition 2018 or current version
- MCS Guide MGD 003: 2022 issue 2.0 *Determining the Electrical Self-Consumption of Domestic Solar Photovoltaic (PV) Installations with and without Electrical Energy Storage.*
- MCS Standards Document MIS 3012: 2021 issue 1.0 *The Battery Standard (installation)*

(c) the person installing the source of energy ensures that the distributor is advised of the intention to use the source of energy in parallel with the network before, or at the time of, commissioning the source.

This Regulation effectively mandates the relevant DNO notification processes and technical requirements, which are described in ENA Engineering Recommendations G98, G99 and G100.

Energy Networks Association (ENA) Engineering Recommendations

The following ENA Engineering Recommendations form part of the Distribution Code (DCode) which in effect make their use mandatory under the ESQCR:

- G98 (replaces G83) for installations in which the total generation up to 16 A per phase.
- G99 (replaces G59) for installations in which the total generation exceeds 16 A per phase.
- G100 for installations with export limiting systems

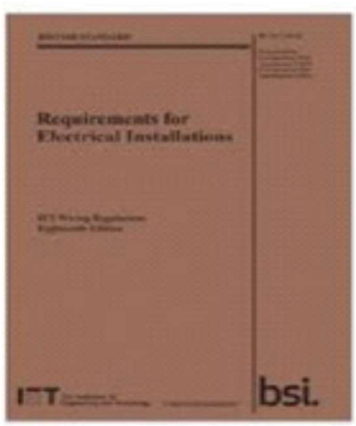
These Engineering Recommendations address:

- Technical requirements for inverters and other associated equipment
- Information on the notification and approval processes for equipment (or, in the case of G99, installations).

BS 7671: Requirements for electrical installations (current version)

BS 7671 *Requirements for electrical installations. (IET Wiring Regulations).*

- Principal British Standard for safety of electrical installations
- Covers protection against electric shock, fire and burns
- Section 551 - Generators (includes electronic converters) & battery installations



Other standards and guidance

- BS EN IEC 62485-1 and BS EN IEC 62485-2 cover stationary secondary battery installations.
    - For EESS that are sold as a pre-manufactured package including lead-acid and nickel-cadmium (NiCad) batteries, the manufacturer should have addressed the requirements of these standards, as applicable.
- BS 7430 is the British Standard Code of Practice for Earthing
    - Should be considered when providing a means of earthing for island mode operation.

Other guidance

- IET Code of Practice for Electrical Energy Storage Systems
- IET Guidance note 1: Selection and erection
- IET Guidance note 3: Inspection and testing
- On-Site Guide
- IET Guide to DC Power Distribution in Buildings
- IET Technical Briefing *Practical considerations for d.c. installations*
    - This technical briefing is free to download at https://www.theiet.org/media/2734/practical-considerations-for-dc-installations.pdf
- MCS Standard MIS 3012:2021 *The Battery Standard (Installation)*

MCS Guidance Document MGD 003 V2.0 *Determining the Electrical Self-Consumption of Domestic Solar Photovoltaic (PV) Installations with and without Electrical Energy Storage*

Section 3

Electrical Energy Storage Systems (EESS)

Section 3 - Electrical Energy Storage Systems (EESS)

There are some main factors that will influence a battery storage system:

- The purpose of the system
- The system architecture
- Whether the EESS system is a pre manufactured package or a custom – designed system
- Whether it is intended for a Grid Connection or operation independently

Purpose of an EESS

An EESS in a typical dwelling or small commercial/industrial installation may be used to:

- Increase self-consumption of local renewable generation (e.g. solar-PV and wind power) – sometimes called time shifting.
- Maximise on the use of tariffs for local consumption, where batteries are charged when prices are lowest, and discharged to local loads at peak periods – sometimes called arbitrage.
- Provide a back-up or alternative power source, in the event that the public supply is unavailable.
- Provide ancillary services, where power from local generation sources can be exported to the public supply at peak periods, or to support the frequency or voltage of the local public supply.

Packaged, bespoke and discrete EESS

A Packaged EESS is a complete solution commercially available as an off-the-shelf product which may be purpose built for use with a specific manufacturers local generation system. The controller and battery are specified by the manufacturer, guaranteed compatibility but this could limit the interface options and the range of system performance.

A Bespoke EESS is where the components are individually purchased with greater reliance on the competence and experience of the designer to ensure:

- The system matches the installation load, grid and generation profile

- Is correctly specified, source tested

- Correctly commissioned in accordance with manufacturers instructions

A discrete component EESS is assembled from two or more discrete components, perhaps from different manufacturers.

	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 performance. Manufacturer includes and tests all relevant safety functions, such as thermal and electrical safety protection, within the package. Operators and maintainers can follow manufacturer's instructions.	Interface options, bespoke options and the range of system performance may be limited. Tied to 'manufacturer-recommended' or supplied replacement components.
Discrete component EESS	Wider choice of interface options. Easier to make the installation bespoke to needs. Freedom to choose products from different manufacturers.	Greater reliance on the designer and installer of the system to correctly specify, source, install, test and commission. The design and commissioning stages would require more documentation than other types. The designer and installer need to compile operation and maintenance information to ensure that the 'as-delivered' system can be safely operated and maintained.

Grid-connected inverters

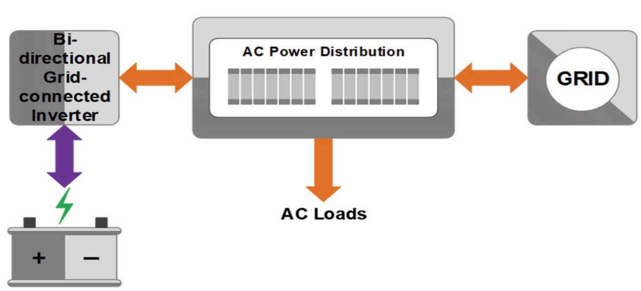
Non-commutating (or pure grid-connected) inverter is when the grid power (mains) is removed, the inverter output ceases. In installation with only non-commutating inverters these do not need an island mode isolator.

Self-commutating (or stand-alone) inverter is when the mains is removed, the inverter continues to supply power (as a switched-alternative to the mains)

Self-commutating inverters require an island mode isolator to be installed

Both kinds of inverter may be bi-directional contain AC-DC conversion for battery charging

Bi-Directional Grid-Connected Inverter



Key and general inverter characteristics

Key characteristics

Bi-directional inverter	Affects
Maximum charge current	The maximum charge the inverter can supply.
Charge profile(s)	The types of charge profile (for different battery types) that the inverter is able to provide.
Stand-aloan inverter	**Affects**
Continuous output power	The power output the inverter can support continuously
Surge capacity	The ability of the inverter to handle surges (both surge power and duration need considering)

General characteristics

Parameter	Usage
Minimum and maximum DC input voltage	Inverter must be able to operate at the lowest nominal DC voltage and withstand the maximum DC voltage of the EESS. Note: This may need to include a consideration of any voltage variations due to temperature.supply.
Maximum input current	Key parameter when specifying DC circuit components (cables, protective devices, isolators etc.)
Nominal AC output voltage & frequency Minimum and maximum voltage and frequency	For grid-connect inverters in the UK, the minimum and maximum output voltage and frequency that the inverter will operate will be set by G98/G99.
Electrical separation	Knowing whether the PCE has a transformer that performs galvanic separation can be a key consideration in the design process (e.g. may influence RCD selection).
Efficiency Power factor range IP rating Ambient temperature range Max. humidity Max. altitude G98/G99 type test status	Important considerations when selecting an inverter for any application and ensuring the inverter is suited to its loads (e.g. power factor for inductive loads).
Warranty	An important consideration for selecting an inverter (and other components of the EESS).

Harmonics

Inverters can generate harmonic content at their output and input, and this may cause compatibility issues with equipment connected to input and output circuits for example:

Some appliances containing electronic controls or variable speed drives are incompatible with connection to supplies that have battery storage or solar PV inverters.

Some signal-phase motors as those in fridges and freezers may experience overheating as a result of too high a harmonic content in the supply for which they have not been designed.

Broadly there are three different types of inverter, each having a different profile

- Sine wave, sometime referred to as 'true sine wave' or 'pure sine wave'
- Modified sine wave
- Square wave

Coupling Modes

- The *coupling mode* is used to describe the way in which a storage battery is connected to the rest of the electrical installation there are two *coupling* modes:
    - AC coupled, where the EESS has its own inverter output
    - DC coupled, where the EESS integrates with local generation via a DC bus in the local generation, such as wind or solar-PV, and uses the inverter for the local generation system

Note: Table 3.1 in the IET Code of Practice for Electrical Energy Storage Systems provides a comparison of AC and DC coupled systems.

AC coupled system

In this system shown below, the battery can charge from the AC mains or the local generation. This type of EESS may be used to:

- Optimise self-use of local generation (time-shifting)
- Maximise on cheap tariffs (arbitrage)
- Provide a (limited) power backup facility.

System classification and Grid-connected inverters

Systems are classified based on the characteristics in the following table, examples of different classes of systems are shown below.

System classification	Battery and PCE	Islanding arrangement (where appropriate)
Class 1	Battery, BMS, PCE and islanding arrangement housed in same manufacturer-provided enclosure. PCE is G98 / G99 type tested as appropriate. No DC cabling outside manufacturer-provided enclosures. Single manufacturer or importer is responsible for performance, safety and warranty of all component products.	Islanding arrangement is housed in the same enclosure as the battery and PCE. Islanding arrangement is G98 / G99 type tested as appropriate Single manufacturer or importer is responsible for performance, safety and warranty of all component products.
Class 2	PCE is housed in a different enclosure to the storage battery and/or BMS. PCE is G98 / G99 type tested as appropriate. DC cabling may exist outside manufacturer-provided enclosures. Single manufacturer or importer is responsible for performance, safety and warranty of the component products.	Islanding arrangement may be housed in a separate enclosure to the PCE. PCE manufacturer or importer is responsible for the performance, safety and warranty of the islanding arrangement. Islanding arrangement is G98 / G99 type tested as appropriate
Class 3	PCE is housed in a different enclosure to the storage battery and/or BMS. PCE is G98 / G99 type tested as appropriate. DC cabling may exist outside manufacturer-provided enclosures. PCE manufacturer is responsible for performance, safety and warranty of the PCE. PCE is G98 / G99 type tested as appropriate. BMS manufacturer responsible for performance, safety and warranty of the battery and BMS products. The MCS Contractor is responsible for confirming compatibility between PCE and BMS.	Islanding arrangement may be housed in a separate enclosure to the PCE. PCE manufacturer responsible for the performance, safety and warranty of the islanding arrangement. Islanding arrangement is G98 / G99 type tested as appropriate
Class 4 (full scope certified MCS Contractors only)	Battery, BMS and PCE may all be from different manufacturers. System does not fall within the definitions of Class 1, Class 2 or Class 3 systems. The MCS Contractor is responsible for (or for arranging by others) system performance compliance, safety and warranty of the component products.	The MCS Contractor is responsible for performance, safety and warranty of the islanding arrangement and its integration with the system controls. Where not type-tested, installer is responsible for performing DNO-witnessed tests and obtaining DNO approvals.

1. Identify

- Ensure the circuits or equipment to be worked on (or near) are correctly identified
- Ensure all potential sources of supply are identified.

2. Disconnect

- Disconnect from **every** source of electrical energy before working on or near any part that is live (or likely to be live).
- Ensure any stored charge is safely discharged.

3. Securely isolate

- Ensure appropriate, designated, means of isolation are used.
- Use padlocks and multilock hasps to prevent inadvertent reconnection of supplies during work.

4. Post notices

- Label all points of disconnection with caution notices so that others know work is being done.
- Danger notices can be placed on adjacent live equipment

5. Prove dead

- Prove dead using a 2-pole voltage indicating device as recommended by HSE Guidance Note GS38
- Check the instrument is working *before* and *after* use.

6. Earthing

- Earthing low-voltage equipment is desirable if there is a risk of re-energisation, e.g. from a generator.
- Consider this carefully - the risk of short circuit may outweigh the benefit of earthing!

7. Adjacent live parts

- There may be other live parts nearby, particularly if you are not isolating the whole installation.
- Consider erecting barriers or temporary insulation.
- Post danger notices at relevant points

EESS Commissioning

The IET Code of Practice for Electrical Energy Storage Systems show examples of system and application tests that might be performed during commissioning these can be found inTables 12.3 and 12.4. However the procedure for commissioning can depend on:

- Type and intended use of the system
- Manufacturer's instructions for:
- Packaged EESS
- Components of a bespoke (tailored) EESS

Where as the requirements of ENA Engineering Recommendation G98 / G99 / G100 as appropriate.

Section 7

Handover and DNO notification