Electrical energy storage and the smart electrical installation

The IET Wiring Regulations (BS 7671) are based on European standards, which in turn are usually based on International standards. One new area of possible development within International standards is a new section within IEC 60364 covering smart electrical installations to incorporate energy efficiency measures, interface with the smart grid and manage renewable sources of electricity. One key area of the smart electrical installation is electrical energy storage.

Chief Electrical Engineer Geoff Cronshaw takes us through secondary batteries and, in particular, lead-acid batteries for electrical energy storage and the smart installation.

Smart electrical installations: what are they?

A smart installation is defined as an electrical installation that can operate connected to the grid (supply network) or isolated from the grid by optimally controlling elements such as dispersed generation (for example, photovoltaic panels or wind turbine), electrical energy storage equipment (for example, batteries), and the various loads (for example, motors, heating, lighting, appliances such as washing machines) by using an information exchange.

There are a wide range of micro-generation technologies, including solar photovoltaic (PV), wind turbines, small-scale hydro, and micro combined heat and power (CHP).

One of the key components of the smart electrical installation is the electrical energy management system (EEMS). The objectives of EEMS are:

- to control the connection of the smart electrical installation to the smart power grid;
- to locally manage the electrical energy production;
- to manage the electrical consumption; and
- to manage the energy procurement from the grid (supply network). This is carried out using meters and measuring equipment in order to communicate correct electricity parameters to the EEMS and the direction of energy flow.

Individual, collective and shared smart electrical installations

The proposals in IEC 60364 pertain to the possibility of individual smart electrical installations, collective smart electrical installations and shared smart electrical installations.

Individual smart electrical installations are considered to be an electrical installation (for example, a private house or workshop) that can either produce or consume electrical energy. Three operating modes are considered for the individual smart electrical installation:

- direct feeding mode (where the installation is supplied from the grid (supply network));
- autonomous mode (where the installation is supplied from its own generator); and
- reverse feeding mode (where the installation supplies electricity back to the grid (supply network)).

Collective smart electrical installations are considered to be a group of smart electrical installations (SEI),for example, private houses, private flats in a building, and small shops in a mall, that have a common electrical power supply from one separate unit producing energy and from the grid (supply network). Three operating modes are considered for the collective SEI:

- direct feeding mode (where the installation is supplied from grid (supply network);
- autonomous mode (where the installation is supplied from its own generator); and
- reverse feeding mode (where the installation supplies electricity back to the grid (supply network).

Shared smart electrical installations are considered to be a group of individual neighbouring houses that may group their interests and share their supply with their each other from their own renewable power sources. Each house owner may have installed private renewable energy power sources that can either supply the private electrical installation or supply the group of private electrical installations. Three operating modes are considered:

- charging mode (where the installation is supplied from grid (supply network));
- autonomous mode (where the installation is supplied from its own generator); and
- reverse feeding mode (where the installation supplies electricity back to the grid (supply network)).

Metering: the smart electrical installation

Metering is an essential part of the SEI. In the individual SEI, meters and sensors measure and detect energy flow. Metering is provided to measure energy supplied both from the grid and supplied back to the grid (for example, where the installation includes PV panels or a wind turbine). Electricity generated on site by the installations' own micro generation technologies is also metered and energy supplied from storage units such as batteries is metered. In addition, metering is provided to measure energy that is consumed by the various loads, such as motors, heating, lighting etc. The collective and shared SEIs include a wide range of meters and sensors to monitor and control energy.

Electrical energy storage: what is it?

Electrical energy storage systems can be divided up into three main classifications, mechanical (pumped hydro, compressed air, flywheel), electrochemical (secondary batteries, flow batteries, hydrogen), and electrical (double layer capacitor, super conducting magnetic coil, thermal-sensible heat storage).

There are two main classes of battery: lead-acid batteries and alkaline rechargeable batteries. Alkaline rechargeable batteries, such as nickel-cadmium, nickel-metal hydride and lithium ion, are widely used in small items such as laptop computers. In this article, I'll be focusing on lead-acid batteries.

Lead-acid batteries

Lead-acid batteries are the most common large-capacity rechargeable batteries. They are the world's most widely used battery type and have been commercially deployed since about 1890. Lead-acid battery systems are used in both mobile and stationary applications. Their typical applications are emergency power supply systems, stand-alone systems with PV, battery systems for mitigating output fluctuations from wind power and as starter batteries in vehicles.The lead-acid cell uses lead and lead oxide plates immersed in sulphuric acid electrolyte. The nominal voltage of a cell of lead acid is fixed at 2.0 Volts.

The two main types of lead-acid batteries are ‘open vented’, which is a secondary cell having a cover provided with an opening through which products of electrolysis and evaporation are allowed to escape freely from the cell to the atmosphere, and ‘valve regulated lead acid battery’, known as VRLA.

Open vented batteries

Open vented is generally older technology and requires a separate battery room, must be stored and used in a vertical position and requires regular routine maintenance. Open vented batteries are typically constructed with transparent or translucent containers through which the electrolyte level and internal components are visible. Each cell is continuously vented through a flame arrestor on the top of the container.

VRLA batteries

The VRLA battery is sealed, except for a pressure relief valve that opens in case of internal overpressure. The electrolyte is not a free liquid as in a vented cell.

A bank of VRLA cells is often installed differently from the open-vented battery bank. As mentioned, open-vented cells must sit upright on racks, while VRLA batteries have fewer limitations on cell orientation because the electrolyte has been immobilized. They are self-contained and only require a low level of maintenance.

By design, VRLA cells emit very little gas during operation. However, there are some conditions that may cause a VRLA cell to vent hydrogen:

- during an equalize charge or elevated float charge;
- whenever float voltage is higher than recommended; and
- during the first few months of operation for a gelled electrolyte cell.

Locations where VRLA batteries are installed should therefore include adequate ventilation.
Challenges of lead-acid batteries

Great care should be taken when dealing with battery installations, during design, installation itself, use and maintenance. The manufacturer’s instructions should always be followed.

In abnormal conditions, such as short-circuit, the current may only be limited by the internal impedance of the battery and may be very high. Under these circumstances, this energy may be released very quickly and unexpectedly. This can happen when the terminals of the batteries are accidentally short circuited. In the event of short circuit a large amount of current flows through the fault, resulting in heat, which could cause danger.

Lead-acid batteries are usually filled with electrolytes, such as sulphuric acid. These very corrosive chemicals can permanently damage the eyes in an accident and produce serious chemical burns if the chemicals come in contact with the skin. Under severe overcharge conditions, hydrogen gas may be vented from lead acid batteries and this may form an explosive mixture with air. Adequate ventilation and correct charging arrangements should always be observed. The manufacturer’s instructions should always be followed.

Challenges faced when designing a d.c. installation

There are a number of challenges when designing a d.c. installation. Persons involved in d.c. installations need to have the necessary expertise. Electrical equipment used on a d.c.

installation must be suitable for direct voltage and direct current. Equipment approved to normal a.c. standards may not be suitable, especially switchgear. Given the nature of d.c., additional requirements need to be taken into account when disconnecting a d.c. load. This is because an arc can occur when disconnecting a load, which is more difficult to extinguish compared with an a.c. load as there is no natural zero point on d.c. compared to a.c. Arc quenching circuit breakers for overcurrent protection is an area that needs special consideration. The arc produced when disconnecting a fault on a d.c. installation is more difficult to extinguish. Designers of d.c. installations will need to liaise with manufacturers of equipment and exercise careful consideration when selecting a circuit breaker for use on d.c. installations to ensure that the circuit breaker has suitable arc-quenching capabilities and are suitable for the operating voltage.

Safety issues, interaction with HV public network, energy storage and functional issues

The proposals on SEIs include requirements for earthing when in any of the three operating modes (direct feeding mode, autonomous mode, and reverse feeding mode).

Protection against overcurrent is also included. It is proposed that overload and short circuit currents shall be determined in all points of the SEI where a protective device shall be installed for all possible configurations of the type of SEI, and for situations corresponding to the minimum and maximum current magnitudes. The proposals on smart electrical installations require compliance with IEC 60364-4-43, which is the international standard that chapter 43 of BS 7671 is based on.

Interaction with HV public network including, active and reactive power control, voltage control, frequency control, and load shedding are mentioned, and, of course, energy storage, including electric vehicles, are a key part of the smart installation.

Requirements of BS 7671:2008 (2013)
Chapter 55 – Other Equipment, Regulation 551 – Low Voltage Generation Sets

It is important to point out that there are mandatory requirements for the parallel connection of generators before they can be interconnected with the supply network. In addition, Chapter 55 of BS 7671:2008 (2013) contains requirements for low voltage generation sets. This set of Regulations includes additional requirements contained in Regulation 551.2 to ensure the safe connection of low-voltage generating sets, including small-scale embedded generators.

The Electricity Safety, Quality and Continuity Regulations 2002 (as amended) (ESQCR)

Solar PV power supply systems are required to meet the Electricity Safety, Quality and Continuity Regulations 2002 (as amended) as they are embedded generators. However, where the output does not exceed 16 A per line they are small-scale embedded generators (SSEG) and are exempt from certain of the requirements provided that:

- the equipment should be type tested and approved by a recognised body; and
- the consumer's installation should comply with the requirements of BS 7671:
    - the equipment must disconnect itself from the distributor's network in the event of a network fault; and

- o the distributor must be advised of the installation before or at the time of commissioning.

See 'Engineering Recommendations G83/1, for PV systems up to 16 A (5kw) and G59/1', published by the Energy Networks Association (ENA) for larger systems and generators, etc.

Conclusion

Please note this article is only intended as a brief overview of issues being considered at a very early stage. As such, they may not lead to new international standards. This article is based on draft proposals and, therefore, the actual requirements (if it became an international standard) would probably be different.

It is understood that there is currently a lot of work ongoing in the UK looking at large-scale energy storage (upwards of 2.5 MW) using all types of battery chemistry configurations, which OFGEM and the distribution network operators (DNOs) are involved in under the Low Carbon Network Funding. An Electrical Energy Storage Systems Good Practice Guide (funded by the Department of Energy & Climate Change) developed by the DNOs (via their Energy Storage Operator Forum) should be published and publically available towards the end of this year.