
Autumn 2014

Protection against electric shock

BS EN 61140 tells us that hazardous live parts shall not be accessible and that accessible conductive parts shall not be hazardous live, when in use without a fault or in a single fault condition. In this article, Richard Townsend, Senior Engineer at the IET, looks at the fundamental rules governing the requirements for protection against electric shock.

Put simply, protection from shock under normal conditions is provided by basic protective provisions referred to as 'basic protection', such as insulation. When the installation is in a single fault condition the shock protection is provided by fault protective provisions referred to as 'fault protection', which normally involves an automatic disconnection of supply (ADS) using overcurrent protective devices. In this way, shock protection is provided whilst the installation is in use, whether without a fault (basic protection) or with a single fault condition (fault protection).

This is in keeping with Regulation 410.3.2, which requires a protective measure to have the following characteristics:

410.3.2 A protective measure shall consist of:

(i) an appropriate combination of a provision for basic protection and an independent provision for fault protection, or

(ii) an enhanced protective provision which provides both basic protection and fault protection.

Additional protection is specified as part of a protective measure under certain conditions of external influence and in certain special locations (see the corresponding Sections of Part 7).

NOTE 1: For special applications, protective measures which do not follow this concept are permitted (see Regulations 410.3.5 and 410.3.6).

NOTE 2: An example of an enhanced protective measure is reinforced insulation.

Fundamentally, BS 7671 only provides guidance and protection against single fault conditions. In a healthy and properly designed installation, we apply one or more protective measures, taking account of external influences that may adversely affect it. The protective measures that we generally permit in BS 7671 are:

- ADS;
- double or reinforced insulation;
- electrical separation for the supply to one item of current-using equipment; and
- extra-low voltage (SELV and PELV).

Automatic disconnection of supply

ADS is the most widely used protective measure. Its purpose is to limit the magnitude and duration of the voltage between exposed conductive parts of a circuit and other exposed conductive or extraneous conductive parts so as to prevent danger.

ADS is a protective measure that includes both basic and fault protection. These two forms of protection are described in BS 7671 as follows:

(i) basic protection is provided by basic insulation of live parts or by barriers or enclosures, in accordance with Section 416, and

(ii) fault protection is provided by protective earthing, protective equipotential bonding and automatic disconnection in case of a fault, in accordance with Regulations 411.3 to 6.

All electrical equipment is required to comply with one provision for basic protection as described in Section 416 of BS 7671. These measures can include:

- basic insulation;
- barriers;
- enclosures; or, in certain circumstances,
- placing the electrical equipment out of reach.

Fault protection is provided by:

- protective earthing;
- protective bonding; and
- automatic disconnection in the event of a fault.

Protective earthing

Protective earthing ensures that the circuit protective device will disconnect the supply in the event of a fault and limit the rise in potential, above Earth potential, of any exposed conductive parts during the fault.

Protective bonding

Protective bonding is required to minimise any potential difference between exposed conductive parts and extraneous conductive parts during a fault. The outcome of bonding these two parts together is to equalise potential and not to carry fault current; however, in some cases, bonding conductors may carry fault current where they form a parallel earth return path to the source of supply during the loss of a neutral conductor in a PME supply.

This highlights that the term ‘Earth bonding’ should not be used when applying earthing or protective bonding.

Examples of extraneous conductive parts that may require bonding include:

- water installation pipes;
- gas installation pipes;
- other installation pipework and ducting;
- central heating and air-conditioning services; and
- exposed metal structural parts of a building.

Automatic disconnection in the event of a fault

ADS in the event of a fault is achieved when the circuit protective device operates within the required time period for a given supply system. This is dependent on circuit design parameters and limits, which are not the focus of this article. In TN and TT systems an overcurrent protective device or an RCD may be used to provide circuit fault protection. There are specific requirements when using RCDs for fault protection that should be adhered to. Reference to RCDs is made in Regulation 411.4.4 for TN systems and TT systems are referenced in Regulations 411.5.2 /411.5.3.

In certain circumstances, RCDs are also used for additional protection where more onerous situations are present, see Regulation 411.3.3. Relevant sections of Part 7 also stipulate the use of RCDs, when required, in special locations. Understanding the different types of RCD is now important as new inclusion to BS 7671, Section 722, includes specific reference to RCDs of types ‘A’ and ‘B’.

Once all the basic and fault protection requirements for ADS have been met we can say that the electrical circuit/installation/system has shock protection.

Double or reinforced insulation

This type of shock protection is not very common and requires that only equipment that is of a class II construction, which has double insulation or reinforced insulation, is to be used in the installation. To that end only equipment with no exposed conductive parts that may become live in the event of a fault can be used.

Double insulation uses basic protection provided by basic insulation and fault protection is provided by supplementary insulation

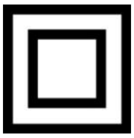
Reinforced insulation is where the protection is provided by single or basic insulation but has the same protective properties as double insulation.

In both cases, the installation does not require a protective conductor and must therefore have effective supervision in normal use. This type of protection must not be used to supply socket outlet or luminaire couplers, which could allow the accidental inclusion of a class I piece of equipment.

In some cases, manufacturers will apply reinforced insulation to a piece of equipment for use in a standard installation. In these cases, the installation will not provide shock protection via double or reinforced insulation; moreover, the equipment is protected in this way and would therefore not require effective supervision whilst in normal use. An example of this is where some manufacturers of recessed down lights use two single insulated cables to connect the lamp holder to the circuit connector outside of its enclosure. The cable used for the connection in this way has single insulation but its properties are that of double insulation.

Allowable wiring systems for use with double or reinforced insulation systems are also tightly referenced; they must be enclosed in either a non-metallic sheath or other non-metallic conduit or containment system and have a rated voltage greater than the nominal voltage of the system and at least 300/500 V.

As a general rule, equipment must be clearly marked with the double square symbol, indicating it is class II, see below:



In instances where equipment to be used in this type of system only have basic insulation, the installation must have supplementary protection applied to it during erection, to provide a measure of safety no less than that of class II equipment. The equipment must also be clearly marked with a symbol to indicate there is no earth present, see below:

Likewise, equipment having un-insulated live parts must have basic and supplementary insulation provided. If this cannot be achieved it is allowable to use reinforced insulation as long as in doing so a degree of protection not less than class II is provided. Again, a symbol to indicate no earth present must be clearly displayed on the equipment.

Electrical separation for the supply to one item of current-using equipment

Shock protection, via electrical separation, for a supply to one item of current using equipment, is provided when fault protection utilizes simple separation of the circuit from the main circuit and all of its associated circuits and Earth. Basic protection is provided by insulation or barriers.

When the basic protection fails in this type of installation the fault protection is afforded by simple separation from the main circuit because it has no fault path to Earth and therefore no electric shock. The downside of this is that with the loss of basic protection the fault is generally not cleared and goes undetected until there is a second fault, which may prove to be hazardous.

A generator commonly utilizes this type of simple separation, which is isolated from the main installation and not connected to Earth or any other earthed circuit. It is vital when using this type of protection method not to allow any exposed conductive parts of the equipment to be connected to the protective conductor or exposed conductive parts of other circuits. Another very common example of this type of protection is a shaver socket. See below for diagram of a generator supplying one item of current using equipment:

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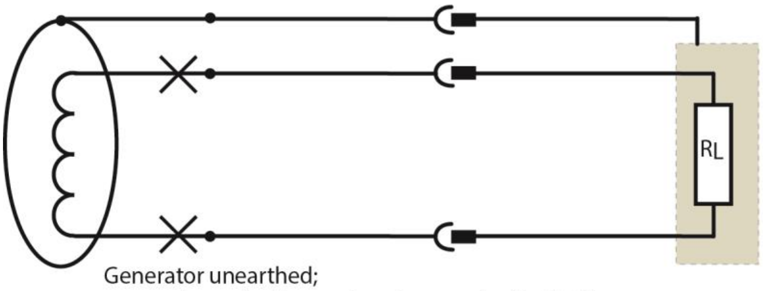


Electrical separation may be used for more than one item of current using equipment; however, the risks associated with this are greatly increased. Extra measures are required to ensure that the installation is safe. These measures include the requirement of the installation to be under the supervision of skilled or instructed persons in order to ensure that no changes are made that could lead to a dangerous scenario. Warning notices must also be present to control the connection of protective bonding conductors as these must not be connected to Earth.

> The protective bonding conductors associated with the
> electrical installation in this location
> MUST NOT BE CONNECTED TO EARTH
> Equipment having exposed conductive parts connected to earth must not be brought into this location

Extra-low voltage (SELV and PELV)

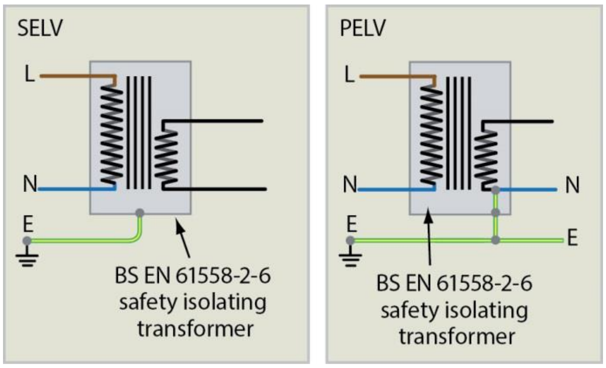
Shock protection by separated extra low voltage (SELV) and protected extra low voltage (PELV) are the same. This is arguably the safest measure as there are three protective provisions in play:

- the limitation of voltage (limited to a voltage not exceeding 50V a.c or 120V ripple free d.c);
- the protective separation; and
- basic insulation.

By its definition SELV is electrically separated from Earth and so a single fault cannot result in an electric shock.

Protection from contact with normally live parts is provided by basic protection in the form of enclosures, barriers or basic insulation. If the nominal voltage of a SELV system or device does not exceed 25Va.c or 60Vd.c, protection from contact with normally live parts is negligible and may depend on the design use of the equipment. For example, some SELV lighting track systems will have the track section live, whilst in use, allowing the user to move the luminaires freely along the length of the track. The touch voltage in this case is not considered to be hazardous in general use.

SELV and PELV supplies are those supplies that are specified as safety isolating transformers in BS EN 61558-2-6. They are almost identical – in so much as both have a primary and secondary winding. The main difference is that the SELV transformer has no connection between Earth and its secondary winding whereas the PELV transformer has a connection to Earth from the secondary winding. Examples of these types of supplies are shown below:



It is for this reason that where a PELV transformer is used and the nominal voltage does not exceed 25V a.c or 60V d.c, in a normally dry location, the exposed conductive parts must be connected by a protective conductor to the main earthing terminal for the installation, where protection against contact with live parts may be omitted.

Fault protection in a PELV system is provided by the primary circuit protection, given the secondary winding's connection to the installation earth terminal. One downfall of a PELV system is that faults elsewhere in the installation are likely to induce voltages on the PELV system through its protective conductor.

The downside of a SELV system is that it must be totally separated from any LV circuits as it does not utilise any protective conductors. To this end, the overcurrent protection in an unearthed SELV system dictates that, where required, devices are present in both live conductors. The need to ensure total separation in a SELV system and the lack of protective conductors requires the use of socket outlets that are not interchangeable with LV or other ELV systems present in the same property. This will further reduce any likelihood that a connection to Earth can be made in error.

Further information on shock protection can be found in the IET publication Guidance Note 5: *Protection Against Electric Shock*.

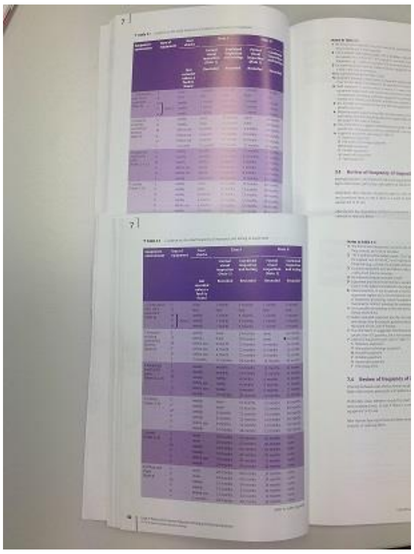
Wiring Matters
Your insight into BS 7671 www.theiet.org/wm

Counterfeit alert: Code of Practice for In-service Inspection and Testing of Electrical Equipment (4th Edition)

As many of you are aware from our previous articles on the subject (see 'The counterfeit issue' from Wiring Matters 50 – March 2014), some of our titles have been the focus of counterfeiters. Whilst we appreciate that everyone likes to get a good price for the necessities, buying from places such as Amazon MarketPlace and eBay can lead to inadvertently obtaining counterfeit copies of our books. We've found some significant errors in these fake titles and urge you to please buy from established retailers – we've put together a list of recognised retailers.

The fake titles we have been aware of so far are the On-Site Guide and the Wiring Regulations themselves. These are important books that most of you will be using either in your studies or on the job. If you follow the erroneous information in these books, you could either fail your exams or follow incorrect information in your line of work – which could well lead to fire and safety risks. Unfortunately, even though you can prove that you followed the information in your book, you could still be liable for prosecution if your work leads to fire, safety hazards or death – so please do take care with your purchases.

The most recent fake that we have discovered is the *Code of Practice for In-Service Inspection and Testing of Electrical Equipment (4th Edition)*. This fake is easily identifiable by the spelling errors; see an example below from Table 7.1:



You will see that the heading 'Equipment environment' is missing the 't' at the end, and that 'Not recorded unless a fault is found' appears as 'Not recordet unless a fault is found'.

We'd like to thank everyone who has contacted us after watching BBC Fake Britain featuring this subject, or after reading through our previous articles on this. Please continue to let me know if you have spotted any fakes: wiringmatters@theiet.org.

Near disaster on a railway caused by rats signals continued vigilance for cable installers

An investigation that concluded that rats caused a collision between two trains, leaving 40 people injured, highlights the constant battle between animal pests and man's vital infrastructure, says Dr Jeremy Hodge, chief executive of the British Approvals Service for Cables (BASEC).

At the beginning of July, a high-speed TGV train was struck from behind by a regional train in south west France. The regional train had passed a signal wrongly set on green and the potentially catastrophic malfunction was caused by rodents gnawing through trackside signal cables, an SNCF inquiry found.

The accident at Pau has prompted the French national railway to carry out an urgent check on 10,000 signals to prevent any further occurrences of what it says was an 'exceptional and unprecedented' incident.

But Dr Hodge says that the threat from rodents and other animals to cabling and the systems they carry is always with us, and presents serious challenges to specifiers, installers and end-users.

"We receive many enquiries about how to protect cables against rats, mice, squirrels, pigeons and even insects – with the first three the most pernicious and determined.

They can gnaw at cables to create nesting material. Rats must gnaw as their teeth grow constantly and it does not help that a rat's tooth is harder than iron. Cables under floorboards, in outbuildings and in ducts are commonly affected, including power, data, final circuit installations and fibre cables. The wiring looms of motor vehicles are also regularly attacked."
Dr Hodge says that preventing vermin damage has three lines of defence. The first is building in physical barriers or deterrents, such as routing cable to avoid spaces in which rodents live or travel, for example, under floors, or embedding cables in conduit, plaster, cement or concrete.

Secondly, selecting the most suitable cabling for use where vermin might be present is recommended. Regular cable such as PVC conduit wire or flat twin and earth offers no protection against gnawing. However, steel wire armoured or steel braided cable offers some protection, though the sheathing itself may be attacked. Mineral insulated cable or steel conduit offer good protection.

It is possible to include deterrent additives – a bad-tasting chemical - into the sheathing material of some cables. But these have limited effect with mice or rats and they are mainly used overseas where damage from insects, including termites, is a significant problem.
Finally, controlling the pests themselves is an effective way to prevent or reduce further problems. Seek advice from specialist firms but less costly is to make sure holes, cavities and voids – even the smallest – are blocked up in buildings and that any source of food from waste and litter is removed.

The IET Wiring Regulations BS 7671 set specific requirements for designers and contractors to assess 'External Influences' such as fauna (coded as AL), in Section 522.10. The normal condition (AL1) is 'with no vermin present'.
Where 'aggressive fauna' are experienced or expected (AL2), an appropriate choice of wiring system or special protective measures must be used, such as cable with better mechanical protection, by using more appropriate routing or locations for the cables, or by providing additional protection such as conduit.

Cables gnawed through by vermin can result in electrical short circuits and fires and, as in the case of the Pau train collision, are significant threats to life and safety. It is unlikely that we are going to declare victory over rats, mice and squirrels soon but by remaining vigilant and adopting sensible preventive measures we can help guard our vital systems and infrastructure against their attacks, says Dr Hodge.

Further information about BASEC is available at www.basec.org.uk or you can contact BASEC directly at mail@basec.org.uk or +44 1908 267300

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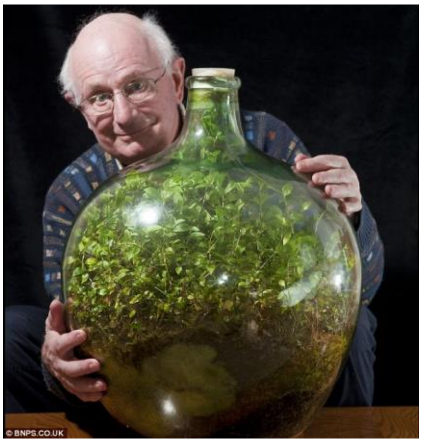
Your insight into BS 7671 www.theiet.org/wm

Spotlight: David Latimer



We're somewhat dazzled today having industry heavyweight David Latimer in the Spotlight seat. David has had a truly illustrious career within the standard-setting processes of the Wiring Regulations, culminating in Chairman of the IEC (worldwide) and CENELEC (European) Committees from 1990 to 2002. Now retired, David is still closely connected with the IET, having been a member of the IET for over sixty years and through his involvement with BTNET, the IET's Built Environment Sector.

You started off your career in electrical contracting. How did you end up steering Wiring Regulations internationally as Chairman of IEC as well as the UK's IEE Wiring Regulations committee?

In about 1963, at the time of metrication, the man representing the Electrical Contractors Association of the IEE Wiring Regulations Current Ratings Panel left his company just before a meeting of the Panel. I was asked whether I could attend for one meeting, at the end of which I was asked whether I could come to the next meeting. I received the papers for the next 40 years.

In 1968 when IEC TC 64 was formed, the structure of the Wiring Regulations Committee was changed and the Technical Sub-Committee set up. I was to have been a member "believed to be in touch with contracting interests", as it was then expressed, and a former Vice President of the Institution was to have been Chairman, but he withdrew and I was asked whether I would Chair the Committee. With the support of the uncle with whom I worked, I accepted.

I was a UK delegate to TC 64 and I must have impressed the other delegates because, in 1990, I was asked whether I could accept the Chair of IEC TC 64 and of CENELEC TC 64. As I was then working for myself, I gave myself permission and remained Chairman for the full 12 years permitted by the IEC.

I might add that when I was working for my uncle's company I got all the time I needed. When the company was sold I was given a number of days a year and the rest came from holiday; when I joined the ASEE it was all taken from holiday and when I started working for myself it was ,of course, all in my own otherwise chargeable time.

You were Chairman of the various committees during a period of change, as around the time of the 15th Edition of the Wiring Regulations, European requirements were first adopted by the UK. What was it like leading that change and how did the industry react?

You must realise that, back in the 1970s, David Brice, the Technical Secretary of the Institution of Electrical Engineers, carried enormous weight in the development of the content of the Regulations and the wording; if the Technical Subcommittee was going in a direction which he did not like, I had to stop the discussion and the item would reappear on the agenda until the Committee decided the way David wanted. This is not so say that David did not consult a small coterie and might change his mind.

Adopting the new layout and adapting our content to it, while integrating new IEC requirements and discussing and deciding the UK response to the IEC document, was burdensome and we met monthly. One of the problems was to determine what exactly the 14th Edition intended and to analyse how the IEC proposals agreed with or conflicted with them.

I clearly remember the tense discussion over the question as to whether the principle of safety should be a 50 V maximum touch voltage (safer but impossible to verify) or a disconnection time (not so safe but verifiable) and whether that time should be 0.4 seconds or 0.2 seconds. They nearly had me in tears.

After about 12 years we froze the content and, eventually, after 15 years, the 15th edition came out.

After the 15th Edition came out the industry was, should we say, somewhat dismayed. There was a series of workshops held around the country, and the same question came up, complaining about requirements which, it had to be pointed out to them, were actually in the 14th Edition and its predecessors. There were new requirements and much time was spent in explaining how to handle them.

What have been the highlights of your career?

Undoubtedly my Chairmanship of TC 64 and CENELEC TC 64 but also my Chairmanship of the NICEIC.

The lowlight was accepting Part 7s in the Regulations on behalf of the UK; cleft sticks come to mind

What advice do you have for those installers out there who might like to pursue a standard-setting career?

First of all an employer who will give time, not only to attend meetings but also to study papers and attend international meetings; evening and weekend time is often necessary. While someone may be supported by a trade association and must advance their views, it is also necessary to consider those views in the light of what is expressed by others. Certainly, to attend a meeting and to address only those items that appear to affect your sector is wrong.

The willingness to raise difficult questions like 'why' and 'how' and a willingness to say 'I don't understand that' (and you can be sure that others do not) might not make someone popular but they will be listened to.

Above all, while attending international meetings, remember that the native tongue of other delegates (including the USA and Australia) is not UK English; slow, clear speech and the use of simple words is essential. An understanding of how other countries go about their installations (which are not necessarily inferior to ours) leads to better understanding as to why what is done in the UK, is done.

Finally, we can't forget about your famous bottle garden – a garden in a sealed bottle that I believe you last watered in 1972 and, certainly in 2013, was still going strong. How's it holding up?

It just sits there, never asks for anything, never complains, doesn't appear to change. You never see any dead leaves.

City & Guild courses: an introduction

Around twenty years ago, qualifications in the electrical industry were simple: you passed your 236, perhaps went on to complete the 'C' Course and occasionally updated your knowledge of the Wiring Regulations by passing a 2380. Today there is a whole range of qualifications available from City & Guilds, both to train those wishing to become electricians and for those seeking Continued Professional Development (CPD). So, what are these qualifications and what do they mean?

Peter Tanner, Lead Consultant (Electrotechnical) for City & Guilds, gives us an overview of the City & Guild courses.

Before we look at the qualifications, we need to understand what 'Levels' mean. Qualifications are levelled to allow for progression and to demonstrate a particular competency. All qualifications are levelled 1-8, however, the majority of qualifications in the electrical industry focus on levels 1-4.

Level 1 qualification

- Basic knowledge and skills, and the ability to apply skills with guidance and supervision.

Level 2 qualification

- Good knowledge and understanding, and the ability to perform tasks with some guidance and supervision.

Level 3 qualification

- Detailed knowledge and understanding, and the ability to perform and apply skills independently. Has the ability to supervise others.

Level 4 qualification

- Specialist knowledge and a high level of understanding in a particular area of work. Has the ability to manage and develop others.

Now we have looked at levels, let's look at the particular qualifications for those entering the industry, those who wish to top up their skills and knowledge with CPD qualifications or those who need to consolidate older qualifications to become recognised in the industry.

Trainee Qualifications

These qualifications are designed for those entering the industry with very little or no experience or prior qualifications related to the industry.

2357 (Level 3)

This is the qualification that currently allows the learner to gain approval as an electrician. It is a National Vocational Qualification (NVQ) and is part of the current recognised apprenticeship scheme.

The qualification is made up of knowledge and performance units that are built around the National Occupation Standards (NOS) for electricians. The knowledge units are assessed by a range of assignments, written examinations and online multiple choice tests at a college or training centre. The performance units are assessed on site in the real working environment. Although a trainee does not need to be employed to achieve this qualification, obtaining evidence for the performance units on site is very difficult to achieve if the trainee is unemployed. The qualification also includes the three-day Achievement Measurement 2 assessment, which apprentices must complete at an independent assessment centre managed by National Electrotechnical Training (NET).

As part of the apprenticeship framework requirements, 16-19 year-old apprentices who didn't obtain Grade C and above in their relevant GCSEs must also achieve a certain standard in English, Maths and Information Technology (IT). The tests for these are known as Functional Skills Tests.

2357 usually take three to four years to complete. Successful candidates are eligible for Joint Industry Board (JIB) Gold Card Status.

2365 (Levels 2 and 3)

This is known as the 'Tech Cert' and is intended for those not currently employed within the industry but who wish to be in the future. It is a knowledge-only qualification with limited 'off-site' practical assessment. The qualification is delivered at a college or training centre but students must, at the start of the course, sign a declaration that they understand that this qualification does not allow them to become qualified electricians. Students who gain employment may transfer their knowledge skills to 2357 and complete the performance units of the NVQ on site, as well as an AM2, to become qualified electricians. This qualification typically takes one year to complete each level.

The reason why this qualification is split into two levels is because a number of students may complete one year of study at level 2, consider level 3 too difficult, but still find employment within industry using their good level of skills and knowledge.

7202 (Level 1)

This qualification is intended for those who are not too sure what career direction to take. It includes elements of building services, such as plumbing, and has a number of units that can be mixed and matched to suit the learner. It gives students a basic understanding of industry to allow insight into, and progression onto, a pathway that is eventually chosen. It can be achieved in less than one year but is not an entry requirement for 2365 or 2357. Students who know their intended career path can enter straight into those qualifications depending on their employment status.

Consolidation-type qualifications

These qualifications are intended for those working in the industry but need formal recognition by consolidating previous qualifications.

2356 (Level 3)

This is a performance-only NVQ intended for those who have completed an old ‘Tech Cert’ qualification, such as 2360 or 2330, and have been working in the industry without full recognition for a length of time. It is currently managed by the JIB. Those wanting recognition must register for this scheme through the JIB, who will carry out an audit of previously achieved qualifications. There is no set time for this qualification as it depends on the candidate’s prior knowledge and experience.

2397 (Level 3)

This is known as the ‘Qualified Supervisor’ qualification and leads to recognition by the JIB for Gold Card Domestic Electrician status. It is intended for those who have experience working in the domestic installation environment, but little in the form of formal qualifications. By completing a number of combined knowledge and performance units, candidates can demonstrate a level of competency, and can consolidate qualifications that were previously obtained either in part or in full, in order to become fully recognised as a domestic electrician. There is no set time for this qualification as it depends on the candidate’s prior knowledge and experience.

Continued Professional Development (CPD) qualifications

These are qualifications known as ‘short courses’ intended to enhance, develop and validate industry skills.

2396 (Level 4)

This course is for designers of electrical installations for the purpose of enhancing their skills. It is intended to give designers an insight into installation design. This will include not only what is required by BS 7671 but why these requirements are necessary. It is assessed in two parts: a full-scale design project and a three-hour written examination. This course is typically taught over five days.

2394 and 2395 (Level 3)

These two qualifications replaced 2391 (Inspection and Testing) following consultation with industry bodies who were voicing concerns. As a result, 2391 was split into 2394 (Initial Verification) and 2395 (Periodic Inspection and Testing) for the following reasons:

- apprentices who complete a 2357 NVQ have been rigorously assessed for initial verifications, so why should they be assessed again in this discipline.
- the increasing requirements within BS 7671 led to the need for defined skills in both initial verification and periodic inspection and testing.
- the increasing requirements for the Certification and Reporting for inspection and testing meant that the time requirements for a single short course became unreasonable.
- industry voiced concerns that techniques used for periodic sampling were being incorrectly employed during initial verifications.
- greater emphasis was needed on the management of periodic inspections, such as defining and setting ‘extents and limitations’ as well as responsibilities of persons.
- many electricians or contracting organisations were specialising in either new works (initial verification) or maintenance-based work (periodic) and wanted those specific skills.

City & Guilds has come under some criticism of late regarding the methods used to assess these qualifications and, in particular, the low pass rates for the closed book written examination. We have undertaken a lot of work to improve the language used within the examinations and have seen a substantial increase in pass rates as a result. We do, however, still believe that the examination should remain both closed book and written.

Other parts of the assessment, such as the practical assessment, is, quite rightly, open book; but we strongly believe that the examination remains closed book as inspectors need to have a good level of understanding of the requirements in BS 7671 for alarm bells to ring during an inspection. Any facts, figures or values from BS 7671 that are required in the exam are provided in the paper. Awarding Bodies such as City & Guilds are required to assess qualifications at the level and criteria of the unit. Consequently, if unit criteria require candidates to ‘explain’ or ‘describe’, a written examination is the only suitable way to assess this requirement. Other Awarding Organisations use different methods to assess this, such as multiple-choice, but we do not feel this proves the ability to describe, explain and report on situations.

In today’s world a lot of responsibility lies with issuing certificates and reports, which requires inspectors to have the ability to write reports that contain good technical content.

These courses are typically taught over five days each or seven when taking both at the same time.

2382 (also known as the 17th Edition Course) (Level 3)

This is an open book, online, multiple-choice examination on BS 7671: Requirements of Electrical Installations, which tests the ability to find and understand information in BS 7671. This course is typically taught over three days.

2377 (Level 3)

This is an open book, online, multiple-choice examination and practical demonstration on Portable Appliance Testing (PAT) and is based on the IET Code of Practice for the Inspection and Testing of Electrical Equipment. This qualification has two parts depending on the candidate's role. One is for those inspecting equipment and the other is for those involved in the management of equipment registers. This course is typically taught over two days.

2919 (Level 3)

This is an open book, online, multiple-choice examination and practical demonstration on the installation of electric vehicle charging points. It is based on the IET Code of Practice for Electric Vehicle Charging Equipment Installation. This qualification has two parts. One is for installing in domestic locations and the other is for on-street and commercial locations. Each unit is typically taught over five days.

2393 (Level 3)

This is a qualification based on the building regulations and is an open book, online, multiple-choice assessment. It is intended to demonstrate that candidates have an understanding of the different parts of the building regulations and their impact on work covered under Part P. This course is typically taught over one day.

2392 (Level 2)

This qualification is intended for those who wish to gain confidence and understanding in the field of inspection and testing but perhaps lack experience. It is not an industry-recognised qualification, which is why it is at level 2. It does, however, give candidates confidence and knowledge when used as a stepping stone to 2394 or 2395. This course is typically taught over four days.

What is coming in the future?

Trailblazers

The electrical sector has been chosen as one of the industries to pilot Trailblazers, which is a new approach to Apprenticeship Frameworks. This new approach is intended to give employers much more control over the development and implementation of apprenticeships. The new scheme for our industry is currently under development and is due to roll out within the next year. More details on this scheme will be available soon.

TechBac

The City & Guilds Level 2 (Technical) Award in an Introduction to Electrical Installation Skills is for 14-16 year old learners. It is equivalent to one GCSE (120 Guided Learning Hours (GHL))) and will be on the performance tables from 2017.

It is for learners at school who want to combine general education with learning theory and practical activities related to the Electrical Installation industry.

Learners will study both practical and theoretical aspects of the subject. The qualification includes these mandatory subjects:

- structure of the construction industry;
- environmental and sustainability measures in the construction industry; and
- electrical installation wiring and enclosures.

Learners will gain a broad understanding of the Building Services Engineering sector, developing academic and study skills through practical tasks and transferrable skills, which will allow progression into a broad range of next steps.
These skills and knowledge will be of value in further studies, such as an apprenticeship, a Level 2 or Level 3 full-time specialist qualification, or A levels, which can help learners to progress to higher education.

For more information about City & Guilds, please see http://www.cityandguilds.com/. For book purchases, you can buy directly from the IET's webshop: http://electrical.theiet.org/books/exam-guides/.

WiringMatters
Your insight into BS 7671 www.theiet.org/wm

Forthcoming events: what's on, when

Electrical Safety Management: a structured approach to assessing and controlling your own risk

When and where: 5 November 2014, IET Glasgow: Teacher Building

This event, based on the IET's *Code of Practice for Electrical Safety Management*, provides a comprehensive overview of the fundamentals of electrical safety and a systematic set of principles for assessing and managing electrical safety in any business and across all sectors of industry and the public sector.

Who should attend?

The event is applicable to a wide range of workplaces, including manufacturing, construction and service industries, and is essential to managers, engineers and technicians responsible for reducing risks from electrical hazards and ensuring their organisation stays in business.

Find out more about the event.

Wiring Regulations update seminar: BS 7671: 2008 (17th Edition) Amendment 3
When and where: 12 February 2015, IET Birmingham: Austin Court

Amendment 3 is due to be published in January 2015. This seminar will not only provide you with an overview of the changes but give you an opportunity to ask members of the JPEL 64 committee how and why some decisions were made. This will ensure you understand how to comply with the regulations when they come into force in July 2015.

Who should attend?

If you are involved with the design, installation and maintenance of electric wiring in buildings you need to know about Amendment 3.

Find out more about the event.

The effect of mechanical cooling on lamp colour and efficiency

When choosing an integrated lighting and cooling solution for an office development, potential colour shift and efficiency problems must be taken into account. Lamps and LED arrays are designed to give their optimum output and stated colour temperature at a given atmospheric temperature. If lamps are cooled below this temperature, their colour will shift and their efficiency will fall. This can result in the lighting installation delivering below its design intentions. The Society for Light and Lighting provides us with insight into how to take these considerations into account.

Cooling methods

Traditionally, mechanical cooling in office spaces has been dealt with either by cooling air before it is supplied into a room, or using local cooling units that use a fan to force air across a cool surface. Either method can result in differing temperatures across an office ceiling.

Centralised cooling systems

In large buildings, the air supplied to its office space can be chilled centrally and supplied via insulated ductwork to where the cool air is needed. Air, supplied by diffusers positioned within the ceiling, is typically cooled to 6 - 8 degrees centigrade below the ambient temperature of the space to be cooled. The chilled air flows from these cooled spaces via either dedicated extract grilles or a plenum ceiling that incorporates perforated ceiling tiles.

Whilst such a system has no obvious connection to the lighting within the space, care should be taken that the luminaires are not positioned too closely to the supply diffusers due to the ‘Coanda effect’. This phenomenon (first applied by Henri Coanda) results in air that leaves a confinement (through, for example, a supply diffuser) tracking a surface close to its exit point (for example, the ceiling). As long as the surface remains smooth, the effect can carry air across a ceiling for some distance, depending on its discharge rate. Where a luminaire is recessed into a ceiling and has a smooth curving reflector, it is possible for air to flow into the luminaire and across the lamp.

Where air is extracted via a ceiling plenum, the rate of any air flow through the ceiling will depend on the location of the extract ductwork above it. For example, a space 20 metres long and 7 metres wide with an extract point above the ceiling at one end of the room will see a higher volume of air extracted close to that end. The end of the room farthest away will consequently have a lower level of extract volume.

Again, this may not appear to be related to the lighting installation, however, higher extract air flow at one end of a room can result in the luminaires, particularly if they are open, being subject to different ambient conditions across the space. This leads to slight changes in light output and possibly colour from the lamps in these luminaires.

Image of supply diffuser and suspended luminaire

Fan coil units

The principal of operation is to run a cooling medium, such as chilled water, through a series of finned pipes, similar in look to a car radiator, and known as a 'cooling coil'. A fan is then used to push air across that cooling coil and into the space to be cooled.

These units are usually referred to as 'fan coil units' (FCU) and, whilst they can be wall- or floor-mounted, they are usually hidden away in ceiling voids with only their supply diffusers and, sometimes, extract grilles, readily visible. Often, the system will supply air to a space via supply diffusers and extract it to ceiling voids through perforated ceiling tiles, similarly to centralised systems. This latter method can give a more balanced flow of air across the luminaires in a space than can be achieved through specific extract grilles. It also eliminates the possible problems found with the single-point extract in centralised systems because each FCU deals with a proportion of the air.

The natural cycle

By its very nature, cool air will fall to the ground and displace warm air, which then rises. If the supply of cool air is maintained, a cycle will develop. However, it is not simply a case of providing a space with cool air at any given point and expecting such a cycle to begin and be effective at providing cool air to the whole space. Inevitably, such an approach would lead to localised stagnation and the cooling effect would not be uniform. In addition, condensation could build up on the outer surface of any pipe or duct carrying a cooling medium, such as chilled water or air, if the coolant temperature was too low. Any condensation finding its way into luminaires could lead to component failure, in addition to the associated , such as the risk of electrocution.

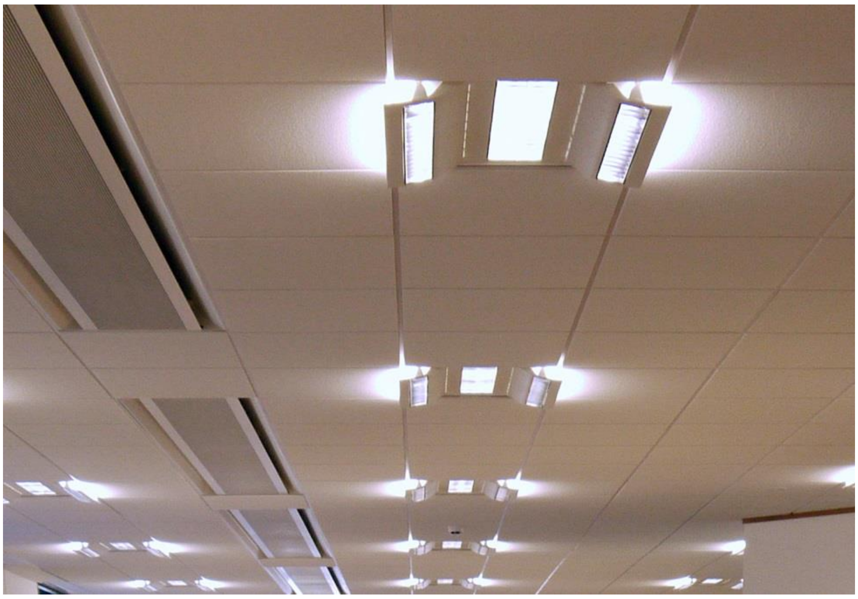


Image of lighting and mechanical services coordination

Chilled beams

In order to gain the benefit of not running fans constantly within fan coil units, and to take advantage of the natural cycle created by falling cool air, the chilled beam concept is becoming more popular in office developments.

Essentially, a chilled beam is a cooling coil that is stretched into a linear section of flow and return pipework, each with a series of radiating fins attached. Because the cooling surface is spread over a much greater area, uniformity in the cooling effect can be achieved without the need to use energy in the running of the fans. However, the risk of condensation on the cool pipework still exists. To ensure that condensation doesn't form, the cooling medium cannot run at temperatures as low as those used in fan coil units.

In addition, the humidity within the space has to be carefully controlled to make sure that any potential water source that could go on to form condensation is limited.

Integrated services

In much the same way as lighting has to be carefully placed in a ceiling to optimise the use of luminaires, components that are associated with the supply and extract of air from a space also require careful placement. This can often lead to the preferred location of luminaires and supply diffusers being in the same place.

When additional services, such as fire alarm smoke detectors, public address speakers, sprinkler heads and movement detectors are added into the equation, it is easy to see how a ceiling can become congested with the inevitable need for compromise.

The need for mechanical services and luminaires to be in the same locations within ceilings to ensure that they achieve their optimal functionality, along with the architectural preference for minimal ceiling congestion, has led to the development of integrated cooling and lighting solutions.

Air handling luminaires

Where cool air is provided from an FCU, it is sometimes possible for the air to return through a recessed modular luminaire. Combining the extract point and the luminaire has the advantage of reducing ceiling congestion and means that both luminaire and extract point can be placed at preferred positions, as discussed.

Care should be taken, however, when selecting such luminaires. Poor design can lead to lamps running below their optimum temperatures when air flows across them and consequently consideration should be given to a number of factors:

- the type of lamp used and its operating temperature: T5 lamps, for example, operate efficiently at a higher temperature than T8 lamps. LED drivers operate more efficiently at lower temperatures.
- the air path through the luminaire: air should ideally pass through the sides of the luminaire and not over the lamps.

Image of integrated chilled beams being installed

Integrated chilled beams

The nature of chilled beams means that such beams occupy a large proportion of ceiling space and so integrating lighting into them is sometimes the only option.

A number of manufacturers offer chilled beams with integrated lighting and presence/absence control.

The issues with beams with integrated lighting are similar to those of air handling luminaires, the difference being that lamps may be subject to cold air falling from the chilled pipework within the beam rather than the returning cold air.

Impact on lighting

Light sources, be they fluorescent, LED or any of the high-pressure lamp types are designed to operate optimally within a specific temperature range. Moving outside of these ranges will affect the efficiency of the lamp, resulting in a lower output and a change in the colour temperature of light emitted.

The effect of temperature on lamps is well known and provision can be made at the installation design stage, provided that the interaction of the various design elements is understood.

Differences in ambient temperature across a ceiling can be caused by either a pre-determined control of mechanical systems, or by unplanned interaction, such as unbalanced extract from an office space.

Where a number of luminaires are installed in a common space and are subject to overall control, drifts in colour temperature and output will not be readily noticeable. However with the advent of better and more precise control of heating and cooling systems, particularly in large open-plan spaces, the effect on lighting can be quite pronounced.

Integrated chilled beams are usually controlled independently of each other, which allows the temperature around any integrated lamps to differ depending on whether the chilled beam is operating or not. Because the lamps are so close to the chilled water circuit within the beams and may be subject to falling cold air passing over them, they are likely to suffer a change in colour temperature.

In relatively small spaces, this may not be noticeable, however in large open-plan spaces, particularly where several beams can be viewed simultaneously, differences in colour temperature will be noticeable.

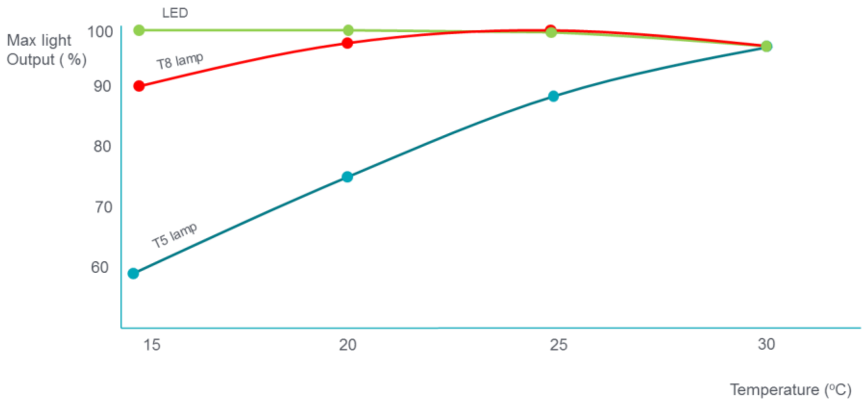
When designing or advising on the use or installation of systems that integrate lighting with mechanical chilled services, the location of lamps within the air-handling luminaire or chilled beam and the air path should be carefully considered.

Whilst not directly related to lighting design, the control of the mechanical systems should be clarified and, where fluctuations in the temperature of adjacent chilled beams is likely to occur, careful selection of integrated chilled beams should be made.

Typical operating temperatures	
Fan coil unit air supply	Typically 6^{o} C to 8^{0} C below the ambient temperature in the space to be cooled.
Chilled beam surface temperature	Typically 14^{o} C to 18^{o} C
T5 lamp optimum operating temperature	Typically 35^{o} C around the lamp
T8 lamp optimum operating temperature	Typically 25^{o} C around the lamp
LED optimum operating temperature	Typically 25^{o} C

Typical performance curves for T8, T5 and LED drivers.

The graph below shows the typical performance curves for T5 and T8 linear fluorescent plus LED drivers over the ambient temperature range that is likely to be encountered in a cooled office space.



It can be seen that the output of the T5 lamps is affected to a greater extent than T8 or LED when the temperature around the lamp falls. If integrated cooling/lighting solutions are not properly designed, there could be a noticeable difference in illumination levels depending on whether the mechanical systems are cooling the space at any given time.

For detailed information and specific lamps characteristics, consultation with the lamp manufacturer should be made.

Energy efficiency: achieving sustainability

Bill Wright, Head of Energy Solutions at the Electrical Contractors' Association, discusses the importance of achieving sustainability through energy efficiency.

Why is it that renewable energy seems to get all the publicity? We continually hear about the latest wind turbines, placed in extreme locations and with the premise being 'bigger produces more'. Biomass systems are 'flavour of the month' as the Renewable Heat Incentive encourages more people to install these systems. PV installations crop up everywhere even though the government can't seem to decide whether or not it wants them; the original tariff was so good everyone installed them then the tariff was slashed, thereby cutting demand overnight. It has been a start- stop scenario ever since and, although the industry seems to have recently settled down to a reasonable level, confusion still reigns in respect of some larger systems.

What seems to have been lost in this mass of renewable energy systems are everyday energy reduction measures, and energy efficiency. It is both cheaper and better to reduce energy than to build new capacity conventional power systems or subsidised renewable power systems. We, as a nation, use far too much energy, and energy prices are continually in the news - but it appears that the price of energy is not high enough yet to force us to take energy efficiency seriously. Many countries in Europe, such as Denmark, which exports wind energy, pay a far higher price.

Domestically, we still continue to use energy-hungry appliances and run our homes inefficiently. Commercially, many firms do not take energy usage seriously, often seeing it as a mundane overhead that does not merit senior management attention. It only takes a stroll through the City of London on a Sunday night to see the number of lights left on in unoccupied offices and hear the A/C systems hum to realise that wasted energy is not even on the 'to-do' list.

Yet it is cheaper and more sustainable to reduce energy than to produce it, by whatever means. The government has at last realised this and more policies are being produced that encourage energy reduction rather than energy production. Commercial energy users should realise that energy costs come straight off the bottom line so any reduction in energy boosts profits. The cost of electricity is forecast to potentially double by 2020 so any cost saved now will reap additional benefits in the future. If your energy bill is £500k, which it is for many firms, then saving just 10% (generally easily achieved) will give an additional £50k profit. By 2020 this profit could double to £100k.

How do we do this?

Energy efficiency is not the rocket science or black art that many suppliers would have you believe. Major savings can be made by a series of small steps, and useful savings can be made at no cost if no initiatives have previously been applied.

- Do you know what your current energy usage is and what it costs? You would be surprised at the number of firms that do not monitor their energy bills or even understand them. Start by looking at, and noting down, the cost and energy usage per month. Suppliers will provide itemised bills, so these figures are easily available. Allocate a person to do this on a regular basis and build up a picture of what your energy usage is. There is an old energy proverb – 'you cannot manage what you cannot measure'. How true.

- If in doubt, turn it off. There are constant cries of “we can’t turn that off- it is essential!”. Look at what lighting is required; do you really need the lights on when the sun is streaming through the windows? Do you really need to keep all the systems on overnight or do you really need to keep your office cooled so it is comfortable to enter first thing in the morning? If in doubt turn it off and see what happens or who complains (obviously taking safety into account).

- At this point you could carry out a simple energy survey of the building and processes. Take a new look at why those lights are on, why switch this machine or that fan on? Take a deep critical look. Even an untrained person can find many areas of energy wastage.

- So far, a lot can be achieved at no cost. You will have gauged the amount you spend on energy and had an initial superficial assessment of the potential for savings. At a small cost, it pays to educate staff on energy basics as they are the ones using it. A simple course on basics can provide major paybacks. If no initiatives have been carried out in the past then savings of around 10% have been made at companies who have educated and incentivised staff to reduce energy usage.

- Once the easy bits have been identified, deeper surveys can then be carried out to identify further savings. These could be undertaken by in-house engineers or trained energy assessors or by external bodies. Many consultants or contractors provide these services, sometimes as part of other work being carried out on the premises.

- After the no-cost initiatives come the more engineering based changes, such as the installation of sensors, change to LED luminaires, installation of variable frequency drives for fans and pumps etc. All of these can be costed and assessed as to whether they are economic. If you are carrying out a survey and have provided costs it pays to find out what the financial requirements are in terms of return on investment. Many companies have fixed terms for payback and an analysis and business case has to be produced for the accountants who will assess how the cost of energy reduction compares to the return on investment in the core business. In many cases it is more cost effective to invest in energy efficiency than into the core business. It is now also increasingly likely that firms come under pressure from shareholders or those with a stake in the company to say how ‘sustainable’ the company is. This will undoubtedly affect the response from the finance departments!

- As you seek further savings it pays to start monitoring energy usage at more local levels. The suppliers’ meter and any meters at the main incoming switchboard will only give you global consumption. You need to find out where the energy is being used and when. There are an increasing number of easy-to-install meters that can monitor individual circuits. Many systems are now IP addressable, enabling remote monitoring. Once installed, local energy use can be monitored from anywhere in the world, a kind of benign Big Brother. The profiles of energy usage so obtained can give an accurate picture of what is happening and you can hone in on areas of high energy use.

The steps above are all very simple and yet they can have a very high return on investment. There are too many systems for saving energy to go through in a short article, but do the simple, inexpensive things first. You will be surprised at what can be achieved on a small budget. Experiment with switching times and the use of sensors. If the mains voltage is too high and the company has its own transformers, try tapping down the voltage before installing any voltage optimisation measures. When installing a new lighting system use LEDs as first choice. Take advice from specialist engineers. Major savings can be easily achieved.

What is the Government doing?

There are an increasing number of initiatives by the government through the Department of Energy and Climate Change (DECC) and the Department of Environment, Food and Rural Affairs (DEFRA) to encourage consumers to reduce energy. The Carbon Reduction Commitment (CRC) was first introduced to incentivise high-spend users to reduce energy by pricing the carbon they were responsible for. It was changed dramatically by the Chancellor who decreed that the government would keep the income from the purchase of carbon allowances and the cost of carbon would be part of their budgetary process! At the initial £12 per ton of carbon it raised the cost of electricity by about 0.6p per unit. However, this is still an incentive as it makes the rate of return of investment potentially better.

The Energy Performance Certificates (EPC) and Display Energy Certificates (DEC) introduced by the Energy Performance of Buildings Directive all have recommendations for the recipient on what measures can be undertaken to reduce the energy use and improve the rating.

There have been recent Consultation Documents, Private Rented Sector Energy Efficiency Regulations (Non-Domestic) and Private Rented Sector Energy Efficiency Regulations (Domestic), which sought feedback about minimum energy performance standards in the private rented sector. It is proposed that all properties being rented out should reach a set minimum, E, EPC level. If this is not reached, the landlord must bring it up to this minimum level of energy efficiency before it can be let. This could have a profound effect on the private rented sector!

Another initiative is the requirement for all FTSE listed companies to publish their Greenhouse Gas Emissions in their company reports. This forces companies to at least look at their energy usage and carbon emissions.

A very recent addition to this encouragement is the Electricity Demand Reduction auction. This is a £10M pilot auction to encourage companies to reduce their demand (though not necessarily their consumption) at peak times in the winter.

The recently published EU Energy efficiency Directive requires governments to ensure that regular audits are carried out on larger companies' energy consumption. The Energy Savings Opportunity Scheme (ESOS) is being introduced to meet this requirement. All eligible companies will have to have an energy audit carried out by December 2015 or they may be subject to penalties. Guidelines have recently been published by DECC and companies will have to carry out four-yearly audits. One drawback is that they do not have to implement the findings of the audit. It is hoped that many will see the advantage in carrying out the efficiency recommendations produced in the report.

Finally, the much-maligned and often-ignored 'Green Deal' is an attempt to encourage householders to install energy efficient measures that are paid for by a loan that is fixed to the house, not the owner. This has not taken off as was hoped because of a variety of reasons, mainly due to lack of incentives and high interest rates on the loans. A recent incentive scheme that gave additional grants was 'sold out' rapidly, showing that incentives can work! The Green Deal has had very limited success with commercial premises, due in some part to the legal complexities.

Energy Efficiency is the first thing that should be carried out before any installation of other power sources. It can easily repay any investment and as we have seen it is far better to reduce energy use than to only look for new ways to produce it.

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

- 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.