WiringMatters #49

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IMPROVING PROSPECTS FOR TECHNICIANS

Study highlights need to provide better career development for technicians in the electrical sector

IET Electrical excellence

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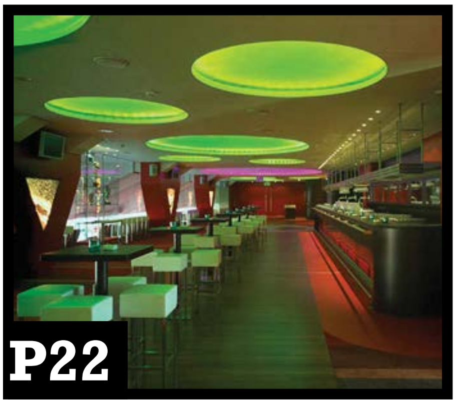

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Electrical excellence

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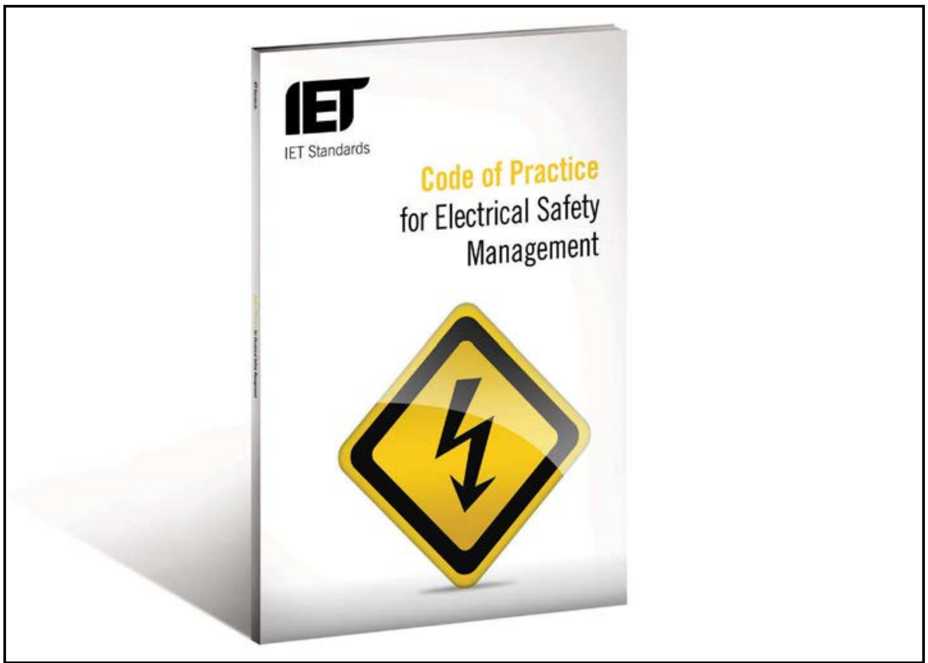
IET introduces code of practice for electrical safety



THE INSTITUTION of Engineering and Technology has launched the Code of Practice for Electrical Safety Management which has been developed by IET Standards.

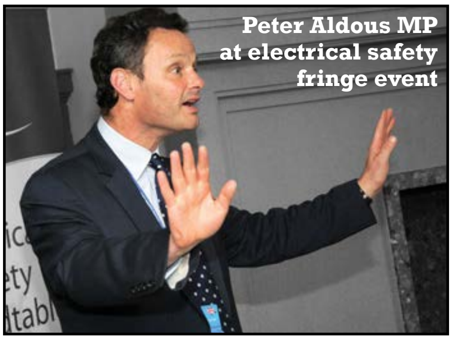
The new code provides a comprehensive overview of the fundamentals of electrical safety, as well as a systematic process for assessing and managing electrical safety in any business. It provides a good-practice guide in the form of a self-assessment, ensuring that anyone who looks after an organisation's electrical system can follow a methodical approach to understanding his or her organisation and the management of the various aspects and risks of an electrical system.

In addition, the guidance included in the code of practice is also intended to be understood and used by a broad range of individuals – whether from technical or non-technical disciplines – the reader can easily implement or enhance an effective electrical safety management system.

The code of practice is suitable for every size of company to use and gives comprehensive coverage of the full scope of safety management. This is of particular importance to those involved in the manufacturing and construction industries where the likelihood of electrical related accidents occurring is so much higher.

Malcolm Sarstedt, group process safety lead at Unilever and chairman of the IET standards development committee comments: "This new Code of Practice is eminently suitable for large and small firms and will be very useful for hard-pressed managers who do not have time to research what to do, and who would be reassured to comply with a product from an influential and authoritative source such as the IET."

The Code of Practice for Electrical Safety Management can be purchased in print and digitally from www.theiet.org/esm-pr. To find out more about the new requirements for electrical installations, you can also speak to an expert at the IET on 01438 76559 or email technical@theiet.org.



Peter Aldous MP at electrical safety fringe event

Politicians listen to safety concerns

THE ELECTRICAL Safety Roundtable (ESR) hosted the fringe event Electrical Safety: Why Regulations Matter at both the Labour Conference in Brighton and the Conservative Conference in Manchester during September.

The panel included politicians as well as representatives from NAPIT, the LABC, the Chief Fire Officers Association and the IET, all present to discuss key issues affecting electrical safety in the home. The issues raised included concerns over the dilution of Part P of the Building Regulations, the importance of individual competence and possible ways of improving Building Regulation enforcement. Consensus on the importance of raising consumer awareness about electrical safety in the home and the need for industry collaboration to help achieve this was evident throughout both events and the ESR was congratulated on its activities to help realise this.

Chairman of the Electrical Safety Roundtable Chris Bielby said: "We are pleased with how well the events have been received and, in particular... interest in reviewing the dilution of Part P. We got our key messages out to a number of influential stakeholders at and raised awareness of the issues surrounding electrical safety in the home. These fringe events were an ideal opportunity for us to ensure MPs hear an industry perspective on the fine balance of risk and responsibility involved in regulatory change."

NAPIT's chief operating officer, Martin Bruno, said: "It was an honour to sit on the panel of the Electrical Safety Roundtable fringe events at this year's party conferences. It proved a fantastic opportunity to raise awareness of electrical safety in the home and to highlight NAPIT's views on topics such as individual competence. I hope this will be one of many opportunities to bang the drum for policy changes which will make our industry safer."

BiggerPicture #49

LED PROJECT

THE LOUVRE, PARIS

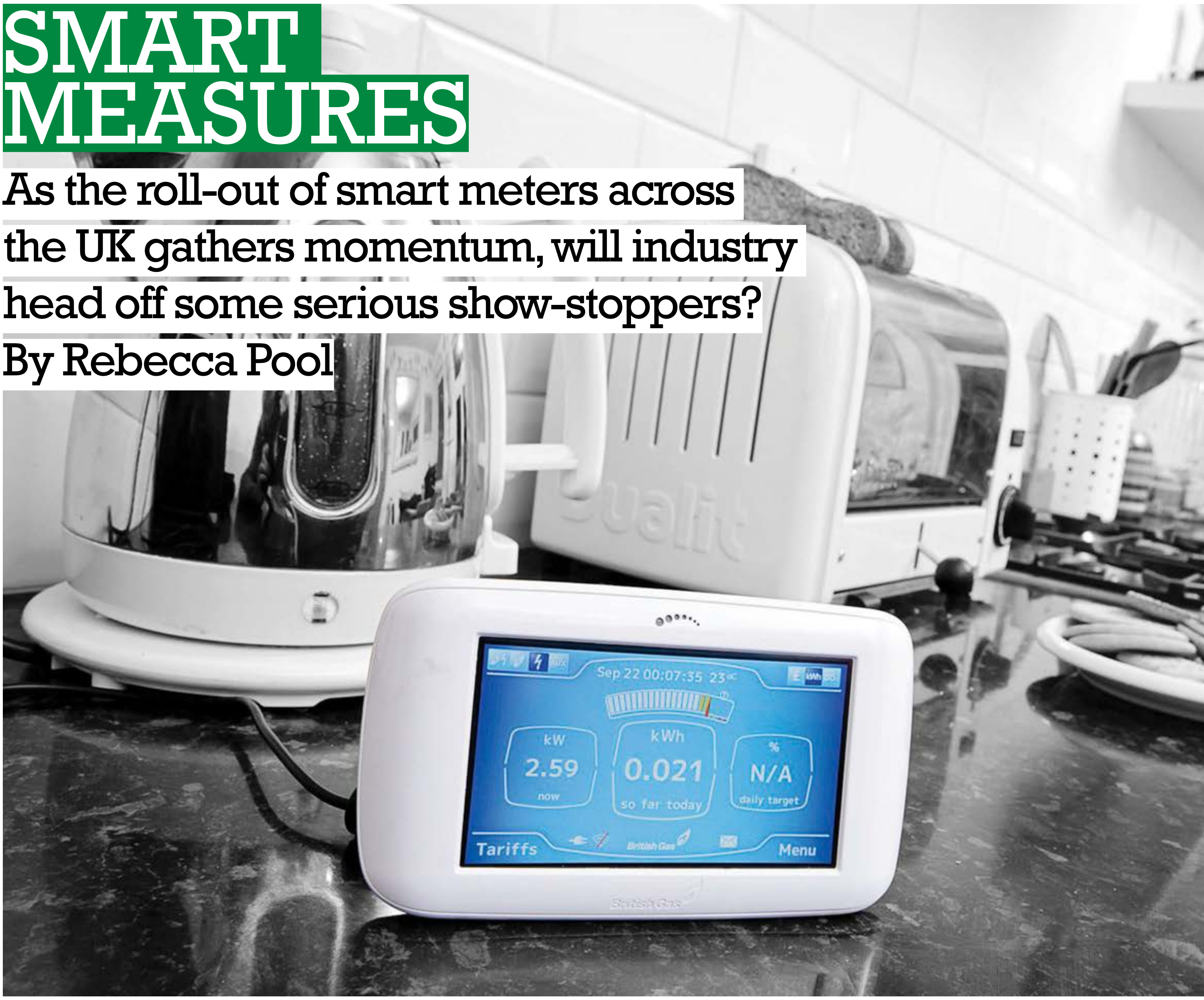
IN THE first phase of a two-stage project, Toshiba is introducing an LED-based external lighting system for the Louvre, Paris. Replacing the existing failure-prone fluorescent lights has dramatically enhanced the visual appeal of the magnificent Third Empire building, while reducing power consumption by 73 per cent. Work on the Cour Napoleon, the site of Pei's famous glass and steel pyramid, was finished in May, and the renovation of all the museum's external lights will be completed by the end of the year.

Agreement has now been reached on the second phase of this project, which will extend LED lights to important interior spaces of the museum, including a dedicated LED lighting scheme for Leonardo da Vinci's Mona Lisa.

SMART MEASURES

As the roll-out of smart meters across the UK gathers momentum, will industry head off some serious show-stoppers?

By Rebecca Pool



IN MAY 2013 the UK government announced that the introduction of more than 50 million smart meters across the nation was to be delayed by just over a year. At the time, the Department of Energy and Climate Change (DECC), which is the government organisation responsible for the roll-out of the meters, stated that communications and energy industries needed more time to design, build, and test systems to ensure the programme was a success. Most industry players doubtless breathed a sigh of relief.

As Lawrence Slade, chief operating officer from industry trade association, Energy UK, puts it: "This has given industry more time; fitting some 50 to 60 million meters is not something you can do overnight, so the extra time was always going to be welcome."

Mass roll-out is now scheduled to start in Autumn 2015, which, asserts Slade, gives the entire sector precious extra months to ensure each part of the supply chain is fully functioning.

"[We] can now make sure the data communications companies are set up and all end-to-end systems testing is in place," he says. "Manufacturers can make sure they are happy with meter specifications, suppliers can ensure plans for installer recruitment are in place and we can start building up consumer confidence much more."

But extra time or not, the reality is installing more than 50 million smart meters in homes and small businesses across the nation is a massive logistical endeavour, riddled with challenges. Consumer confidence is a primary hurdle.

Cost worries

So what exactly is the consumer getting? In terms of devices, a typical home or small business will be installed with a smart meter that comprises an electricity meter and a gas meter. For the domestic consumer, the smart meter comes with an in-home display that provides near real-time feedback on energy usage and its cost. This information should help the user better manage energy use and save money on bills.

Within the home, the smart meter and in-home display are wirelessly interconnected via a smart metering home area network (SM HAN) to the home's central communications hub. If a home generates its own electricity, for example via solar panels, the generation meter that measures energy produced will also be connected to the SM HAN. And in time, consumer devices such as hot-water storage, fridges, freezers and washing machines will also connect to the SM HAN so the smart meter can provide energy data on these devices.

The home's central communications hub will wirelessly transmit the energy data from the home, across a regional mobile network, or Wider Area Network (WAN), to the energy supplier. As DECC highlights, providing suppliers with accurate data for billing in this way removes the need for a meter reader to visit the premises and brings an end to estimated billing. People will only be billed for the energy they use, the meters can be switched between pre-payment or credit mode, and consumers will have easier access to better deals from different suppliers.

Data privacy

For its part, DECC assures consumer privacy over data and has established a programme to boost consumer understanding over how meters work. The government organisation estimates the installation of smart meters over the next twenty years will cost £12.1bn and provide £18.6bn in benefits. It also expects typical consumer consumption will drop by 2 per cent, a figure described as conservative by UK electricity and gas regulator Ofgem.

But as the smart meter roll-out gathers momentum, unease over the programme is surfacing. A primary concern is upfront cost. UK government projects the cost of smart electricity meters to be around £43, with smart gas meters coming in at £56 and displays at £15. Given this and roll-out costs, it predicts that come 2015, bills will increase by £7 a year for the average dual-fuel customer in the short term, until the cost of meters is balanced out over time by the lower operating costs for energy suppliers. But with media reports contradicting this – for example British Gas chief executive Chris Weston is reported to have said energy bills could rise by around £50 per annum – consumer tensions could rise.

"It is not yet clear how easy it's going to be to get meters installed, and I don't think it's at all clear how many visits on average it's going to take to install a meter," says Dr Martyn Thomas, chair of the IT policy panel at The IET. "This has a big implication on cost, and at the end of the day its going to be the consumer who carries all those costs, not the shareholders."

Consumer refusal

And then there's the tricky question of whether the consumer actually says yes to having a smart meter. According to Ofgem, the onus is on suppliers to take all reasonable steps to install smart meters in every household by the end of 2020. Is this realistic?

A 2012 DECC survey into public attitudes, carried out on 120 respondents, indicated that once smart meters and in-home displays are understood, very few consumers felt they would turn one down.

But as Thomas asserts: "At the moment it's not clear that the public will be waiting at their front doors with open arms beckoning in meter fitters. Even if appointments are made, will they be kept?"

Still Energy UK's Slade does not foresee any problems: "Once we start getting the benefits out in the open and debunking some of the risks that have come out, I think people will start coming round to the idea that this is actually a good thing."

John Scott, former technical director of Ofgem and now director of Chiltern Power, believes communications with future customers are going to be key to the acceptance of smart meters. However, he also advocates looking beyond upfront costs.

"You need to look further than the immediate cost of the smart meter because all the opportunities and benefits come from achieving the smart grid and having informed and educated customers," he says. "This is the game-changer for drawing customers to engage with the energy system."

As smart meters are rolled out and consumers become more familiar with how they operate, Scott highlights how demand-side management could considerably reduce the strain on the nation's power grid and reduce energy bills. Here, consumers will shift demand for energy from peak times to periods of lower demand, and crucially suppliers can encourage this load-shifting by enabling tariffs that reward customers for consuming energy during quiet times. Indeed, British Gas is already trialling a 'Free Power Saturdays' tariff for possible launch next year.

"The roll-out of smart meters is just the beginning of what should be a huge range of opportunities," says Scott. "And this active demand side is really important to the economics of the future grid, which is why DECC and Ofgem are pushing hard for smart metering and what it will lead to in terms of demand management."

But as promising as the vision is, hurdles remain. Take the notion of distributed storage, whereby consumers may use large home batteries to store the energy they have generated from their solar panels or other form of distributed generation.

If in the future a customer wishes to use some of his or her stored energy, this is simply not possible given today's >

Ofgem has approved an installation code of practice, outlining how suppliers should give a practical demonstration of an installed meter to a customer and should not conduct sales and marketing pitches when installing a meter. [British Gas]

< wiring, earthing and protection circuits. These networks will need a considerable upgrade to recognise such off-grid operation, and Scott is adamant the industry should be looking at issues such as this now.

Specifications

But while keeping an eye on the future smart grid is key, right now many in the industry are still grappling with the first wave of smart-meter specifications, and other teething problems. In April 2012, DECC released the Smart Metering Equipment Technical Specifications – SMETS1 – that detailed how equipment should be deployed during the Foundation phase of smart-meter roll-out. These specifications included a host of technical detail, but gaps existed, namely with communications network interface standards and security architecture.

DECC has since issued SMETS2, which provides more detail, but still concerns are rife, especially over future-proofing the first wave of smart meters. "Ideally you'd want to design the system in much more detail before starting to install equipment," says Thomas. "The IET has been saying for five years now that given the smarter grid will deliver the benefits, running ahead of the grid architecture and design with meter specifications is a mistake."

"If I was running this programme, this isn't where I would want to be," he adds. "Too many of these difficulties have come about because of the political pressure on timescales. The political timetable has been allowed to dominate over the engineering realities."

Meanwhile John Scott harbours additional concerns over the energy market model for the nation's smart metering roll-out. Unlike most other European countries, network operators are not responsible for metering services. Instead, to boost market competition, the government has concluded that energy suppliers should hold the contract with the consumer and be responsible for smart-meter roll-out, an arrangement known as the Supplier Hub model.

"When you look at the smarter network where, for example, distribution companies wish to access demand side services, you have to ask is this model right for the future?," he says. "Contact with the customer will become enormously more rich and many more opportunities exist than just reading meters and paying bills."

One option would be to hand responsibility over to network operators, but as Scott highlights, to make such a change is hardly trivial. "People are reluctant to raise this as it would bring such a huge upheaval," he adds. "But I do think the Supplier Hub model needs a fresh look."

But amid concerns, other industry players remain upbeat. As Energy UK's >

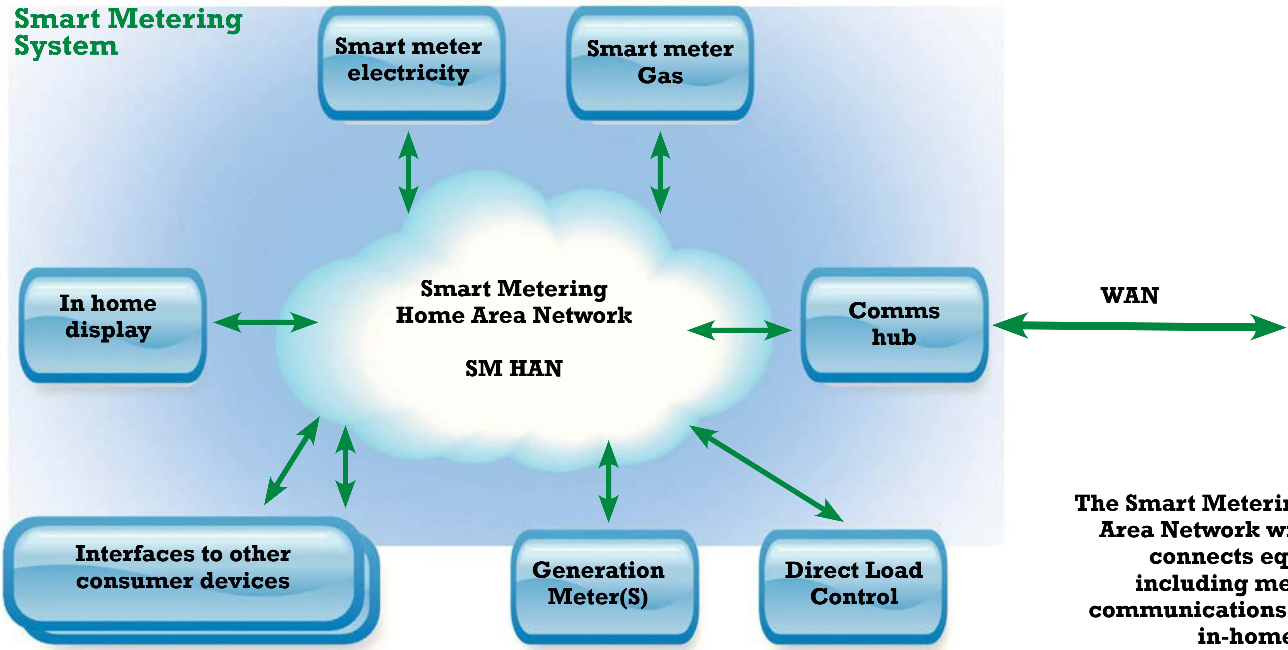
FACT BOX

ROLL-OUT PROGRAMME

The programme of roll-out for smart meters is currently in the second of three phases, the foundation stage. The first 'policy design' phase ran from July 2010 to March 2011 and outlined the proposed design requirements for the different elements of the smart metering system, such as the minimum information that should be displayed on the in-home display.

The second, foundation, phase began in March 2011, and involves DECC working with industry and consumer groups to prepare for mass roll-out. During this phase, industry is building and testing systems with suppliers gaining experience by installing the first smart meters; many thousands will be installed. Also, the Data and Communications Company has been set up, encompassing the key players to provide smart metering data and communications services nationwide.

And finally, the last phase, mass roll-out, is scheduled to start in late 2015 and finish by the end of 2020. During this time energy suppliers will be responsible for replacing over 53 million gas and electricity meters. This will involve visits to 30 million homes and small businesses.



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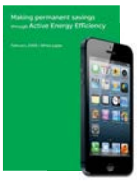

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< Lawrence Slade highlights, the energy suppliers have been heavily involved with the design and content of smart metering specifications. "We're pretty comfortable with this," he says.

And Slade is confident the first, foundation-phase meters will be future-proof. "We're working with manufacturers to make sure everyone is very clear about how a meter that is being put on a wall will be interoperable and how the market will work as the roll-out phase progresses," he adds.

The highest hurdle?

But specifications and future-proofing aside, perhaps the most troubling issue has yet to be truly tackled: the security of data collected by smart meters and transmitted to energy suppliers.

Many in the IT industry are concerned that, for example, unscrupulous consumers could commit fraud by manipulating the data captured by the meter, or a hacker could compromise a smart meter to find out a home owner's minimum energy usage and learn when they are most likely to be out.

But an even greater threat has emerged. As Professor Ross Anderson from UK-based Cambridge University revealed in 2010: "Smart meters contain a remote 'off' switch... to ensure that customers who default on their payments can be switched remotely to a pre-pay tariff. This 'off' switch also creates information security problems of a kind and on a scale that energy companies have not had to face before."

The worry is that a 'cyber-attacker' could hack through a network's security layers and, as Anderson explains, send a command to millions of homes instructing meters to permanently switch off the supply. Or as Scott points out: "If you sent an instruction to open the switches of a large number of meters, you'd disconnect a huge amount of load, which would probably destabilise the British grid."

These concerns have been taken seriously, with government and relevant energy groups working with CESG – Communications Electronics Security Group – the UK government's authority on the security of communications and electronic data to tackle issues. And while measures are underway to make sure the end-to-end security model is robust, DECC has yet to formalise a security specification.

At the time of writing the organisation declined to answer *Wiring Matters'* questions on the security of smart meters and other issues, and many industry players remain uneasy.

"Your implementation needs to be robust enough so you are secure against even a nation-state using serious amounts of resource to break through security," says Thomas. "However, there is no precise statement of what the properties of the [security] architecture are... and then there's the question of whether a security architecture would get implemented properly."

"This is so important and so potentially critical that to rely on informal specification rather than carrying out a proof is irresponsible," he adds. "It's a serious threat and we need to get it right."

Given the grave security concerns, and other issues facing the smart meter programme, is a timely roll-out likely? Thomas has doubts and outlines how projects of this scale tend to over-run.

A smart meter from EVB Energie, Germany. As well as automatic meter reading, the device uses two way communications to reduce load and connect/ reconnect remotely. [EVB Energy Ltd]

FACT BOX
SUCCESSFUL BIDDERS

In August 2013, the DECC awarded its multi-million pound contracts to the companies that are to coordinate the communications and services networks linking the UK's 53 million smart meters with the business systems of energy suppliers, network operators and energy service companies.

The entire programme encompasses numerous data and services communications organisations, all of which are part of the so-called Data and Communications Company (DCC). UK-based business process management organisation, Capita, has been nominated the DCC Licensee to oversee all operations while IT systems consultancy CGI IT UK is to develop and operate the IT system that controls the movement of messages to and from smart meters. Meanwhile UK-based utility and environment consultancy, Gemserv, is to maintain and update industry codes for the use of smart meters.

Crucially, Telefónica UK, will provide the communications network for transmitting data from smart meters to energy companies in the central and southern part of the UK. It will use its existing cellular network, branded O2, supplementing this with smaller wireless networks – called mesh networks – to connect meters in regions that don't have O2 mobile coverage.

At the same time, UK communications company Arqiva will provide the communications network in northern England and Scotland. The company will use a long-range radio communications network, developed by US smart meter communications company, Sensus Technology.

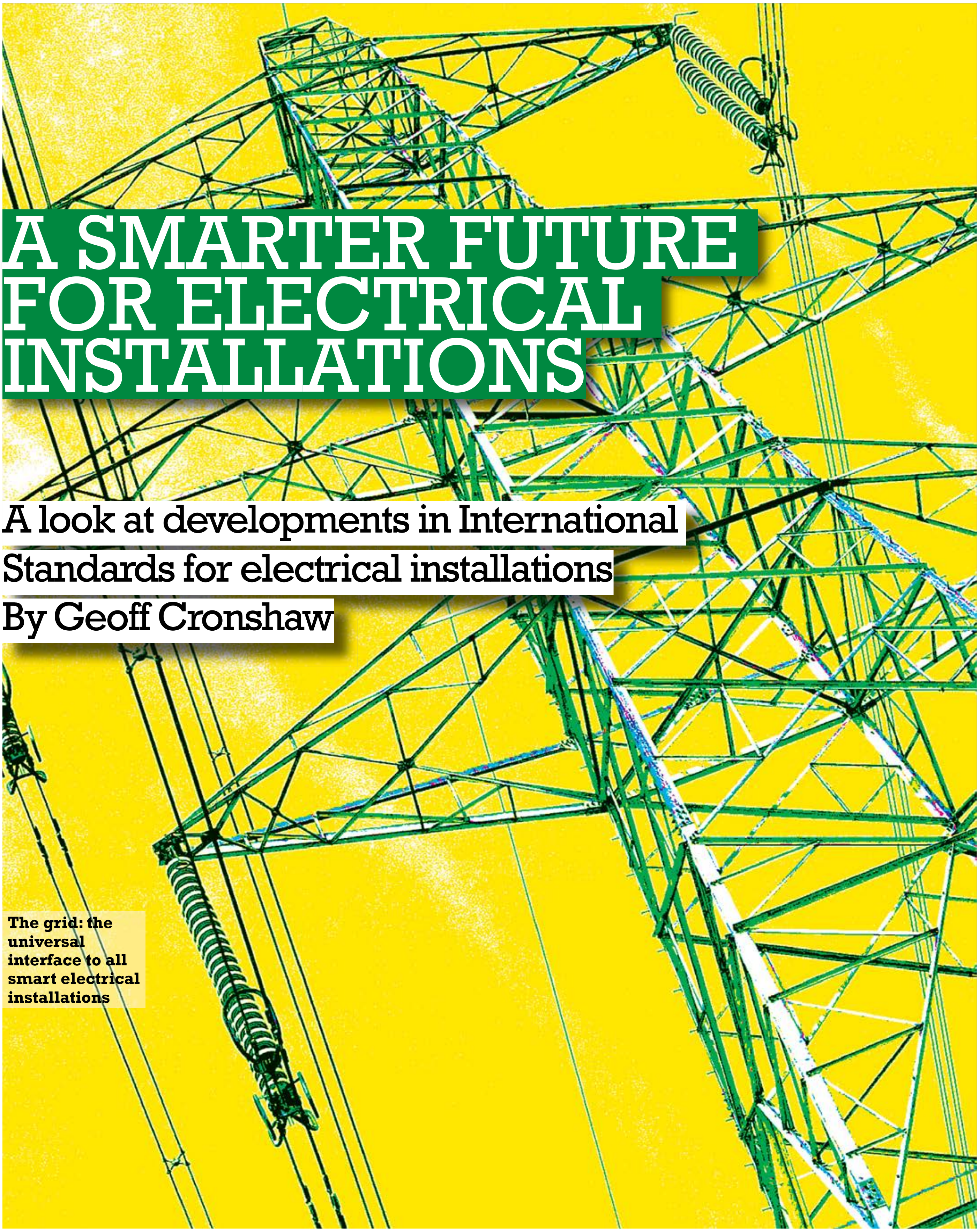
"It's not yet clear that the roll-out can be sensibly completed on the time-scales that government is asking for," he says. "But I think the government will be flexible in the face of reality as it approaches."

However, Scott is more optimistic the necessary smart-meter infrastructure can be put in place to meet roll-out deadlines. "This is a huge logistics task but with good project management, adequate resources and so on," he says. "The conversion to natural gas involved visiting every house and we did that pretty effectively, so why not?"

A SMARTER FUTURE FOR ELECTRICAL INSTALLATIONS

A look at developments in International Standards for electrical installations

By Geoff Cronshaw



The grid: the universal interface to all smart electrical installations

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 proposed within IEC 60364 covering smart electrical installations (SEIs) to incorporate energy-efficiency measures, interface with the smart grid and manage renewable sources of electricity.

The proposals look at 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. These are: 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 SEIs (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 Smart Installation. These are: 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).

Shared Smart Electrical Installations are considered to be, for example, where a group of individual houses may pool their interests in accepting to share their supply with their neighbours from their own renewable power sources. Each house owner may have installed private renewable energy power sources which can either supply the private electrical installation or supply the group of private electrical installations.

This defines a Shared Smart Electrical Installation. Three operating modes are considered for the Shared Smart Electrical Installation. These are: charging 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).

However, it is important to point out that this is only a new work item in IEC at this stage and may not become an international standard. This article is based on draft proposals and, therefore, the actual requirements (if it became an international standard) would probably be different.

The smart electrical installation

A smart installation is defined as an electrical installation that can operate connected to the grid (supply network) or isolated from the grid (supply network) 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 (examples include motors, heating, lighting, appliances such as washing machines) by using information exchange.

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

One of the key components of the smart electrical installation is the Electrical Energy Management System (EEMS). The objectives of the EEMS are to control the connection of the smart electrical installation to the smart power grid, and to manage locally the electrical energy production and consumption. In addition, the EEMS manages the energy procurement from the grid (supply network). This is carried out using meters and measuring equipment in order to communicate the required electricity parameters, along with information on the direction of energy flows, to the EEMS.

Metering – general

Energy measurement is essential for energy management in any electrical installation, not just a smart installation. To be able to measure the amount of electrical energy consumed and monitor and control energy effectively in any electrical installation metering equipment needs to be allowed for at the planning stage. Although this will increase the initial cost of the switchboards, it will prove more economical than having to add metering at a later date.

How metering information will be used needs careful consideration. The system may be required to measure power quality, voltage levels and loads. It may also produce alarms, control loads or change tariffs if pre-set limits are exceeded. Consideration should always be given to the environment where the meter is installed, which should be in accordance with the manufacturer's instructions. Metering needs to be installed in an area that is accessible for the meter reader and where the display can easily be read. Areas where the instrument is likely to be subjected to excessive heat, moisture, and vibration should be avoided. Meters are available that provide pulse generation. These can be linked to building management systems to provide an electrical pulse proportional to a unit of measurement.

Metering – the smart electrical installation

Metering is an essential part of the smart electrical installation (SEI). In the individual SEI, meters and sensors measure and detect energy flow. Metering is provided to measure energy supplied from the grid and supplied back to the grid (for example where the installation includes photovoltaic panels or a wind turbine). Electricity generated on site by the installation's 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 consumed by the various loads such as motors, heating, lighting etc. The collective and shared smart electrical installations include a wide range of meters and sensors to monitor and control energy.

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

The proposals on smart electrical installations include requirements for earthing when in any of the three operating modes.

When designing an electrical installation, one of the first things to determine is the type of earthing system. For an LV supply the Distribution Network Operator (DNO) will be able to provide this information. The system will either be TN-S, TN-C-S (PME) or TT >

Smart installations will have to interface with smart grid energy storage facilities, like this liquid-air-based plant

for a low-voltage supply given in accordance with the Electricity Safety, Quality and Continuity Regulations 2002 as amended.

This is because TN-C requires an exemption from the Electricity Safety, Quality and Continuity Regulations, and an IT system is not permitted for a low-voltage public supply in the UK because the source is not directly earthed. Therefore TN-C and IT systems are both very uncommon in the UK.

Protection against overcurrent is also included. Overload and short-circuit currents are to 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. Energy storage, including electric vehicles. is also mentioned in the proposals.

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 concerning 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. Regulation 551.4.2 covers the use of RCDs. Regulation 551.4.2 states:

"The generating set shall be connected so that any provision within the installation for protection by RCDs in accordance with Chapter 41 remains effective for every intended combination of sources of supply."

Regulation 551.1 includes a note stating that the procedure for connecting generating sets up to 16A in parallel with the public supply is given in 'The Electricity Safety, Quality and Continuity Regulations 2002 (as amended)'. For sets above 16A the requirements of the DNO must be ascertained. The 17th Edition recognises that there are two connection options:

(i) Connection into a separate dedicated circuit

(ii) Connection into an existing final circuit.

Connection into a dedicated circuit is preferred.

Regulation 551.7.2 sets out the requirements for the two options. The Regulation requires that a generating set used as an additional source of supply in parallel with another source shall either be installed on the supply side of all protective devices for the final circuits of the installation (connection into a separate dedicated circuit) or if connected on the load side of all protective devices for the final circuits must fulfil a number of additional requirements. These additional requirements are:

(i) the current-carrying capacity of the final circuit conductors shall be greater than or equal to the rated current of the protective device plus the rated output of the generating set

(ii) a generating set shall not be connected to a final circuit by a plug and socket

(iii) a residual current device providing additional protection of the final circuit in accordance with Regulation 415.1 shall disconnect all live conductors including the neutral conductor

(iv) the line and neutral conductors of the final circuit and of the generating set shall not be connected to earth

(v) unless the device providing automatic disconnection of the final circuit in accordance with Regulation 411.3.2 disconnects the line and neutral conductors, it shall be verified that the combination of the disconnection time of the protective device for the final circuit and the time taken for the output voltage of the generating set to reduce to 50 V or less is not greater than the disconnection time required by Regulation 411.3.2 for a final circuit.

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

Solar photovoltaic (PV) power supply systems are required to meet the Electricity Safety, Quality and Continuity Regulations 2002 (as amended) as they are embedded generators. These are mandatory requirements.

However, where the output does not exceed 16 A per phase they are classed as small-scale embedded generators (SSEG) and are exempted from certain of the requirements provided that:

(i) the equipment should be type tested and approved by a recognised body

(ii) the consumer's installation should comply with the requirements of BS 7671

(iii) the equipment must disconnect itself from the DNO's network in the event of a network fault

(iv) the DNO must be advised of the installation within 28 days of commissioning.

See 'Engineering Recommendations G83/2, for PV systems up to 16A (3.685kW) and G59/3', published by the Energy Networks Association (ENA) for larger systems and generators, etc. Further information can be obtained at: www.energynetworks.org.

Work in progress 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.

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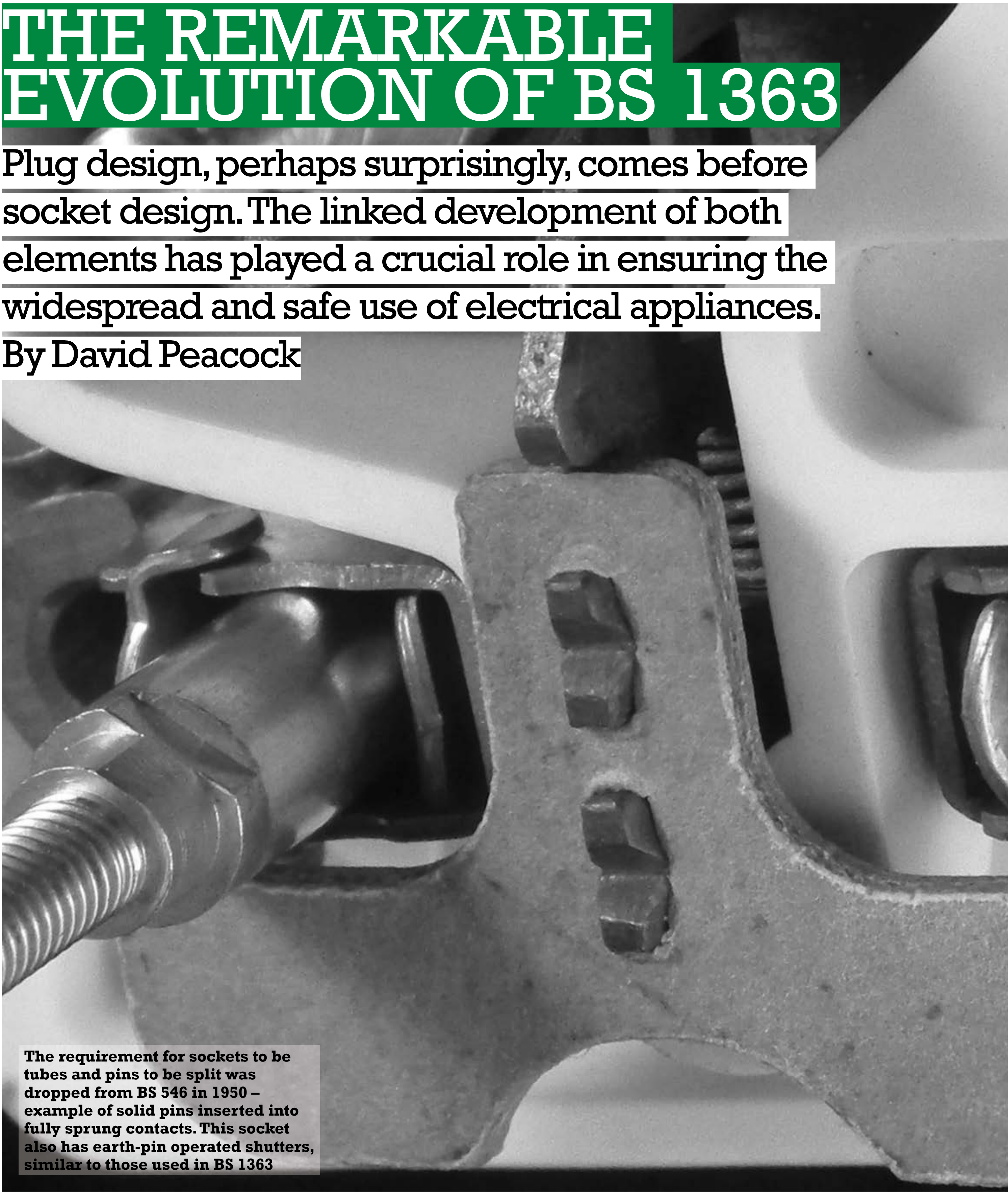
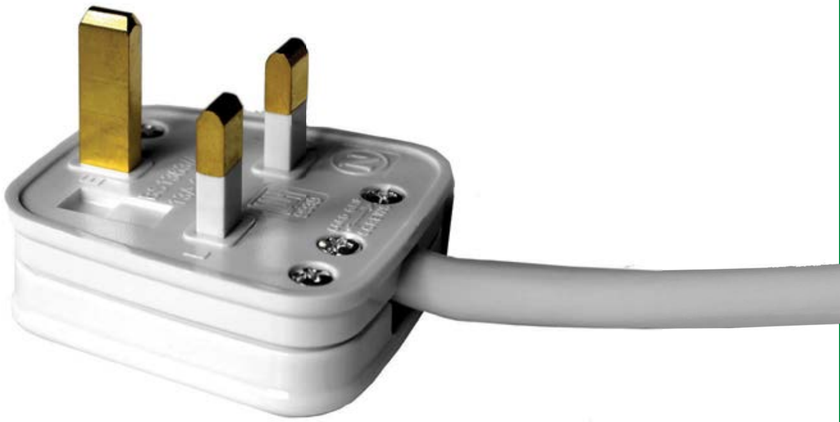
THE REMARKABLE EVOLUTION OF BS 1363

Plug design, perhaps surprisingly, comes before socket design. The linked development of both elements has played a crucial role in ensuring the widespread and safe use of electrical appliances. By David Peacock



The requirement for sockets to be tubes and pins to be split was dropped from BS 546 in 1950 – example of solid pins inserted into fully sprung contacts. This socket also has earth-pin operated shutters, similar to those used in BS 1363



THERE IS A COMMON assumption that a 13A mains plug is made to fit a 13A socket, but actually it is the other way round. The misunderstanding probably arises from the fact that a socket is normally fixed to the building and therefore appears to be the more fundamental and permanent object; however, it is the plug that is precisely defined, and socket designers have a degree of freedom – subject to the socket accepting all compliant plugs. The insertion of non-compliant plugs can damage sockets.

The BS 1363 socket in use today was the result of an extensive and comprehensive study into the needs of post-war housing. It was first introduced in 1947, and many decades-old sockets are still in use. Plugs, being attached to portable appliances, typically have a much shorter life. A plug is a much simpler device than a socket; its pins are a fixed size and are (mostly) held in fixed positions, and it normally has no moving parts. A socket must have self-adjusting contacts and moving shutters to prevent access to live parts when no plug is in place; as such, it is a more complex device. One of the objects of a standard for plugs and sockets is to ensure that all will work together. Today, it is a normal for a plug and socket to originate from different manufacturers, but this was not always the case.

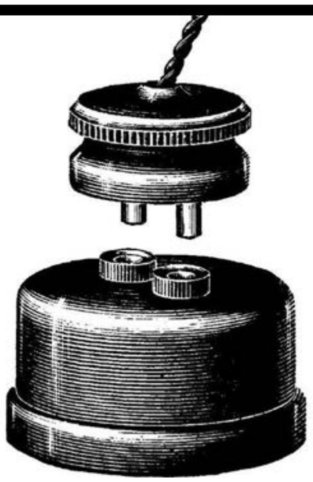
Timeline: plugs and sockets

The following is a list of the significant milestones in the development of British domestic plugs and sockets for mains use (Note: Some types that have not been the subject of a British Standard are not included):

- **1880s – The earliest two-pin plugs and sockets in UK were introduced in the 1880s.**
- **1893 – GEC catalogue includes two-pin plugs and sockets sold only as pairs. Crompton & Co introduced the first shuttered socket.**
- **1911 – GEC catalogue emphasises two-pin plugs and sockets which are interchangeable; plugs also now available separately. Similar plugs are available from other manufacturers including AP Lundberg which also offer three-pin earthing plugs and sockets.**
- **1915 – First official standardisation of domestic plugs and sockets, BS 73, for 5A two-pin. Dimensions of both plug pins and socket contact tubes are specified, slots in pins provide a sprung contact.**
- **1919 – BS 73:1919 adds 15A and 30A two-pin plugs and sockets.**
- **1927 – BS 73:1927 adds 2A two-pin plugs and sockets.**
- **1928 – First official standard for two-pin and** >

earth domestic plugs and sockets, BS 317, 2A, 5A, 15A and 30A ratings. As with BS 73, the dimensions of both plug pins and socket contact tubes are specified, with slots in pins. The pin spacing differs from the two-pin types.**

- **1930 – BS 372 first published. Part 1 superseded BS 73:1927 with minor alterations. Part 2 superseded BS 317 with minor alterations.**
- **1934 – BS 546 first published; superseding BS 372 Part 2 (Part 1 remained the standard for two-pin). The standard specifies interchangeability with BS 372 Part 2, and continues to specify dimensions of plug pins, with slots. For the first time the dimensions of the socket contact tubes are not specified; instead they are required to make good contact with the specified plug pins.**
- **1936 – MK granted patent for earth-pin operated shutter in the form still familiar today.**
- **1947 – BS 1363 published, the first BS to require shutters. The size and shape of the plug's flat pins are fully specified, but the socket contacts are required to operate with plug pins having minimum allowable dimensions.**
- **1950 – BS 546:1950 no longer specified that socket contacts should be tubes.**
- **1984 – BS 1363 modified to require that the line and neutral pins of plugs be partially sleeved to provide an additional level of safety.**



A two-pin plug and socket from the 1893 GEC catalogue

Bakelite 15A earthed plug by GEC to BS 546 – date unknown, but note the use of sleeved pins

1928 wooden-bodied 5A earthed plug by GEC, apparently to BS 317

Ceramic-bodied 15A plug by AP Lundberg and Sons, London, circa 1915

BS 1363

BS 1363 plugs and sockets are defined by having precisely dimensioned plug pins but allowing a degree of flexibility in the design of the socket. Apart from the overall size and the position of fixing holes, the only dimensions specified in BS 1363 for sockets are the minimum distance which the plug must be inserted before live pin contact is made, the maximum dimensions of the pin apertures and their minimum distance from the periphery of the socket. The designer of a socket must take into account the specified dimensions, tolerances and shape of plug pins, and their disposition. The requirement for the earth pin to make and break connection before the live pins is a factor when designing the socket contacts.

Plugs are made by a large number of manufacturers and in many types, including those integrated into adaptors and plug-top devices. It is important that all products intended to be used with BS 1363 sockets conform to the dimensions and required pin shape of a BS 1363 plug. The conformance of a standard plug is controlled by the Plugs and Sockets regulations, other devices intended to be inserted into a BS 1363 socket are excluded from those regulations, but their conformance is equally important.

It should be obvious that the length and cross-section of a pin is critical to its ability to fit the corresponding socket contacts; however it is not uncommon for devices such as chargers, travel adaptors and socket covers to be made with pins of the wrong size. A pin that is too long may prevent the plug being fully inserted, and might damage the base of a socket. A pin that is too thin may not make satisfactory contact with the socket, with the potential risk of arcing and overheating. A pin that is too thick may stretch a socket contact beyond its ability to maintain a firm contact on a conforming pin – and could lead to arcing and overheating when the socket is again used with a conforming plug.

For safety reasons, the line and neutral pins of a BS 1363 plug are required to make contact near their tips only. A pin that is too short, or has a chamfer that extends too far, will not make proper contact. If the line and neutral socket contacts do not apply pressure to the flat parallel surfaces of the pins, but to the angled surface of the chamfer, there will be a squeezing effect, which tends to eject the pins. This effect is often found on socket cover pins which commonly fail to meet the standard dimensions (see http://tinyurl.com/PinPopOut).

By contrast, contact with the earth pin may be made at any point on the pin, and a common feature has been to have the earthing contact extended to the surface of the faceplate. Such a feature does not allow for a widening of the contact mouth, so the chamfer on the tip of the earth pin becomes critical to opening the contact. If there is no chamfer it will be impossible to insert the pin, and any attempt at insertion using excessive force can cause the earth contact to buckle.

BS 1363 sockets are required to have automatic shutters that cover the apertures for the line and neutral pins when no plug is present. The traditional method of operating these shutters is for the insertion of the earth pin to cause a sliding shutter to be moved, thus allowing insertion of the other two pins. This operation depends upon the correct dimensions of the earth pin, and the shape of its tip. If the earth pin is not compliant the shutters may not fully open and, if force is used to insert the plug, damage to the shutters may result. The earth pin method is still used by lower-cost sockets, and virtually all adaptors and extension sockets.

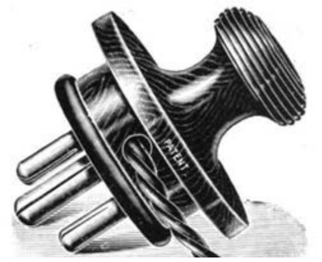
More secure alternatives

From 1957 onwards an alternative, more secure, method of operating the shutters was permitted – based on the simultaneous insertion of any two or more pins. Pressing the pins against the sloping surface of the shutter causes a sliding or rotational movement of the shutter plate to expose the contacts. To avoid operation by a single pin, the shutter plate is normally mounted on a rocker; thus, if pressure is applied on only one side, the other is pushed back on a locking catch preventing opening. Operation by the insertion of a Europlug is prevented by having depressions in the plate to trap the Europlug's 4mm round pins (BS 1363 requires that shutters cannot be operated by a Europlug).

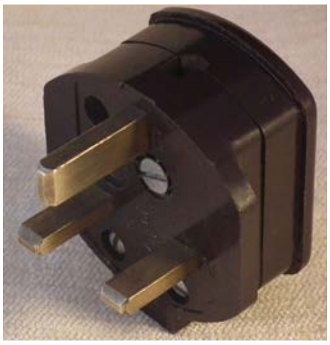
In more recent times the two-pin opening method has been superseded by various patented three-pin systems. In these, the insertion of the earth pin releases a locking mechanism on the shutters, which may then be opened by simultaneous pressure from the other two pins.

The MK and Legrand mechanisms rely on latches operated by the flat sides of the earth pin, the Hagar mechanism uses a latch which is operated by the upper surface of the earth pin. In all cases it is important that the earth pin is of the specified shape and size. If the earth pin (or insulated shutter opening device – ISOD) fails to release the locking mechanism, then the application of excess pressure to the locked shutters while attempting to insert the plug or socket cover may damage the shutters.

One example of this problem is the Clippasafe socket cover which has an 'earth pin' that is non-conforming in a number of aspects. The angled upper surface is incapable of lifting the Hager latch mechanism, and the lack of chamfers prevents insertion into some earth contacts.



A 1891 earthed plug by AP Lundberg and Sons, London – note similarities to the later BS 546 type



Classic early BS 1363 MK 13A plug, prior to the requirement for sleeved

5A two-pin plug with wooden body, probably pre-WW1 [South Western Electricity Historical Society]

Clippasafe socket cover, an example of a product with pins unsuited for use with BS 1363 sockets – the 'earth pin' is the wrong shape

By meeting the requirements of BS 1363-2, the socket designer will ensure that the resulting product will correctly mate with all BS 1363 plugs (those which conform to the 1947 original, or any subsequent version). However, if the dimensions and/or shape of a plug or other device intended to be inserted into a BS 1363 socket deviate from the standard, then it is not possible to predict what will happen when inserted into a socket. Correct interoperability of all plugs and devices incorporating plugs in all conforming sockets can only be assured if BS 1363-1 dimensional requirements are fully met.

The test of time

The members of the committee who originally specified the BS1363 plug and socket were very aware of the need to make provision for entirely unskilled users. They also wanted to make the use of electrical appliances as convenient as possible. It is a mark of the success of the design that it has lasted for over 65 years and has been adapted far beyond the originally foreseen uses.

There are many sockets that have been in use for decades, even possibly some dating from 1947. Many users take these sockets largely for granted and will have a very limited understanding of their technical requirements or the risks which might result from unseen damage. They may equally fail to recognise the signs of damage caused by devices that do not conform to the standard or understand the dangers of damaged contacts. Overheating of line and neutral pins may be an obvious danger but is much greater for unattended appliances or sockets concealed behind large appliances.

Damaged earth contacts may go unnoticed until a possibly fatal accident happens. It unlikely that the vast majority of domestic installations are periodically inspected and tested, except possibly when houses are bought and sold. Even then there is no certainty that every single earth contact, included both contacts of twin socket outlets, will be tested. A damaged earth contact presents an immediate danger as soon as the damage occurs. Many users have little or no understanding of the function of earthing and are unlikely to consider anything but a failure of appliances to work as a fault.

At the time when BS1363 was introduced in 1947, many homes still had no electricity and there was still a widespread apprehension of a potentially dangerous service, if only by analogy with gas. Since then, several generations have grown up taking electrical services for granted. It could also be argued that carefully designed standards and equipment have been so successful in ensuring safety that potential dangers are avoided that they are no longer adequately appreciated. It is therefore all the more important that safety standards are maintained, and above all enforced – both in spirit and in detail.

Effective enforcement of safety standards relies on open and conscientious attitudes unfettered by vested commercial interests and a willingness to take responsibility beyond direct legal responsibilities. Safety, just like freedom, depends on constant vigilance.

David Peacock (david@plugsafe.org.uk) is a retired engineer, a member of PlugSafe, and one of the founders of FatallyFlawed, the campaign to raise awareness of the dangers associated with socket covers in the UK (www.FatallyFlawed.org.uk).

Thanks to Peter Munro MIET (FatallyFlawed).

WHAT IS THE PROBLEM WITH DIMMING LEDS?

White LEDs are revolutionising general lighting markets, but dimming them can cause problems.

By James Hunt

PHILIPS

LEDS HAVE been developed to provide a genuine and affordable alternative to conventional white-light lamps, especially taking into account the total cost of ownership, which will usually easily offset the relatively high initial cost. So successful have LEDs become that LED lighting is genuinely revolutionising the general lighting sector. LEDs are even starting to find their way into homes, despite the still comparatively high initial cost.

LEDs can be designed to produce bright, uniform light, and have many advantages, including relatively high energy efficiency, long life, good reliability and well-directed light output. They are also unaffected by extremely low temperatures and are virtually unbreakable. LEDs can be designed into buildings, structures and materials in ways that are impossible with conventional lighting and can therefore provide more freedom in the design of luminaires, which can be made to look sleek, modern and unobtrusive.

Another advantage is that, because individual LEDs are almost a point-light source, light control is simple, and well-designed LED lighting luminaires – which have special optics – can use virtually all of the light emitted. The high optical efficiency of LED luminaires means that they can achieve the designed illumination for less initial flux (light) than would be needed from a conventional light source (e.g. a fluorescent lamp). Compared with equivalent fluorescents, good-quality LED luminaires will usually make significant energy and cost savings over the life of the installation.

But there is one aspect that is still problematic – dimming. People dim lights for comfort, or to set a scene, but there is also evidence that dim illumination can improve creative performance. A study carried out by researchers from the University of Stuttgart and Hohenheim indicated that dim lighting "elicits a feeling of freedom, self-determination, and reduced inhibition" – all factors conducive to innovative thinking.

Then there is the possibility of energy-saving, though dimming certain types of older lamp can actually reduce luminous efficacy, of which more later.

Clearly dimming is an important requirement and if the LED is to realise its full market potential then we need to be able to dim LEDs with relative ease. We're not there yet, and providing 'dimming capability' is one of the most common problems faced by an

LED lighting techniques can vary colour and dimming for mood enhancement in a hotel lobby

electrician when installing LEDs. The root cause of this problem is that the electronic control gear driving the LEDs is often incompatible with dimmers designed for older lamp types, still in place. To take an example, an LED driver directly connected to a line-voltage incandescent dimmer may not receive sufficient power to operate at lower dimming levels. It may also be damaged by current spikes.

Dimmers used with the now withdrawn incandescent lamps regulate the amount of power to the lamp filament using phase control techniques that incandescent lamps could handle reliably. People didn't notice the inherent flicker because it was too fast.

These characteristics, however, become important when used with compact fluorescent lamps (CFLs) and LEDs. Certain LED lighting products can be used with line-voltage dimmers, but dimmer and LED driver electronics must be carefully matched. However, because already-installed dimmers may vary widely, an LED fixture cannot be guaranteed to automatically work with all dimmers.

The answer is to use dedicated LED dimmers. These typically incorporate low-voltage (LV) controls connected separately to the electronic driver to which full AC power is supplied. This allows the electronic controls to operate at all times, in turn enabling LEDs to be uniformly dimmed to around 5 per cent or lower. However, there is a drawback, as this arrangement may need extra LV wiring for retrofit applications, which can increase the installation cost.

If not properly selected and installed, dimming attempts can give LED lighting a bad name. The solution lies in a proper understanding of the issues.

Dimming issues

Important LED dimming parameters include flicker, colour temperature and efficiency changes.

Flicker – This is an irritating phenomenon. Modern LED drivers typically use pulse-width modulation (PWM) to regulate power, which is a form of fast switching to achieve perceived dimming. To avoid perceptible flicker, the driver output frequency should be at least 120Hz. However, low resolution (the number of bits used to represent values) digital electronics can produce a flicker effect at the lowest settings, but the latest drivers (employing resolutions of 12 bits or higher) avoid this problem.

Colour temperature – When dimming incandescent lamps, the lower filament temperature causes a colour shift from white through yellow to orange/red. Dimming a CFL brings similar results, but much less pronounced. For white LEDs, the light does not shift to red when dimmed; some can even appear more blue, but in any case, colour temperature compensation to obtain the required colour effect may be possible as white light, or other colours, can be produced by mixing red, green and blue LEDs. Of course, the LED lighting system concerned has to be designed to allow this. >

An office using LED downlighting. A study has indicated that dim light can help creativity.

Luminous efficiency is significantly reduced for dimmed incandescent lamps. CFL efficacy is much less affected by dimming, but the luminous efficacy of the latest LEDs can actually improve when dimmed, along with lumen maintenance and longevity. For example, reducing the light output of an LED by two-thirds reduces the current consumption from 525mA to 75mA, in turn reducing the overall energy consumption by 90 per cent.

In general, dimming causes LEDs to experience a similar shift in spectral power distribution as an incandescent lamp, but if coloured LEDs in an array are used to produce the white light, the different spectral shifts among the different colours, particularly with red and yellow LEDs, may adversely affect the overall quality of the white light produced.

When fluorescent lighting is dimmed, the lamp life can be reduced; this does not occur with LED dimming. Instead, dimming LEDs can lengthen the useful life of the LEDs, because the process typically reduces the light source operating temperatures.

How to dim LED lighting

Dimming is achieved by reducing the voltage into, and luminance out of, a light source. LED drivers having a dimming capability can now dim the LED light output over the full range from 100 per cent to 5 per cent, or even zero. Such drivers work by reducing the forward current, by PWM, or via more sophisticated methods. In practice, commercial LED drivers generally use one of two methods to dim mixed-colour RGB (red, green and blue) and phosphor-converted high-power white LEDs.

The first is continuous current-reduction (CCR) – also called 'analogue dimming' – which decreases the forward current supplied to the LED, in turn proportionally lowering the light output level, so the current flows continuously at a set level for a given lumen output.

The second is PWM dimming, in which the frequency could range from a hundred modulations each second to as high as hundreds of thousands of modulations per second, so that flicker is unnoticeable. PWM dimming has the advantage of being less susceptible to colour changes in the LED with varying brightness levels. This is because the LED essentially runs at a constant current when it is on and at no current when it is off. However, this advantage comes at the expense of extra logic to create the PWM waveforms.

Both techniques control the time-averaged LED drive current through the LED (or LED lighting cluster or string), which is proportional to the light output, but the two have their own advantages and disadvantages. Both dimming methods – which are sometimes used together – provide small chromaticity shifts for white LED lighting, with PWM being slightly better than the CCR. Note that mixed-colour (RGB) systems may have the disadvantage of large chromaticity shifts, regardless of the dimming scheme used. Note also that the 1-10V, DMX and DALI technical lighting digital control standards are all compatible with CCR and PWM dimming.

PWM dimming – advantages

- **PWM drivers only run the LEDs at the rated current level or zero, preventing colour and efficiency characteristics from changing as the load is dimmed. The same colour temperature is maintained throughout the dimming range – there is minimal colour shift. This is a significant advantage.**
- **PWM provides a wide dimming range.**
- **PWM drivers provide a precise output, since the LEDs are always on at the rated current (or zero), so the relationship between light output and duty cycle is linear.**

PWM dimming – disadvantages

- **PWM drivers can suffer performance loss if mounted remotely from the light source, because the capacitance and inductance of lengthy cable runs interfere with the fast rise and fall times needed for precision control.**
- **PWM operating frequency must be high to avoid flicker; however, higher-frequency power supplies are typically more complex and expensive, especially for low light levels.**
- **PWM operation may cause electromagnetic interference (EMI) – this may limit the applications.**
- **PWM dimming is typically suitable for LED lighting that must be dimmed below 40 per cent while still maintaining a consistent colour temperature. It is also suitable for colour mixing applications.**

CCR dimming – advantages

- **CCR dimming is simple, requires the least control overhead, and is generally more efficient than PWM dimming because of the lower forward voltage of the LEDs at lower drive currents.**
- **CCR dimming with a Class 2 power supply provides greater voltage than PWM.**
- **In contrast to PWM, CCR dimming doesn't need a complex and expensive higher-frequency power supply.**
- **CCR dimming, unlike PWM, avoids the risk of potentially damaging EMI.**
- **CCR current can in some cases be controlled via amplifier gain, and feedback allows current and thermal foldback for LED protection. Thermal foldback limits the LED temperature to protect against failure by reducing the LED current as the ambient temperature increases. This decreases the current until the LED junction temperature returns to a safe operating temperature, providing greater reliability, and a longer working life.**
- **CCR dimmers can be mounted remotely from the LED light source without significant performance loss.**

CCR dimming – disadvantages

- **CCR dimming needs the analogue voltage to be generated using a separate voltage reference, typically using a digital-to-analogue converter or the output of an RC filter on a square wave input signal. Both approaches can increase costs**
- **CCR dimming can vary**

the colour temperature with the LED current. For certain applications – e.g. in retail outlets – this is unacceptable.

CCR dimming is best suited to those applications where there are long cable runs between the driver and the light engine (a combination of one or more LED modules together with the associated electronic control gear (ECG), also known as an LED driver). An LED module contains one or more LEDs, together with further components, but excluding the ECG.

CCR dimming is also suitable for applications where high-performance dimming is essential, and where there are EMI restrictions. CCR is also suitable for lighting systems needing a higher rated output voltage than the PWM voltage level.

LEDs and dimming for emergency lighting

UK legislation demands reliable, good quality emergency lighting to ensure that people can see and that escape routes are properly identified and illuminated.

Today's high-quality technologically-rich emergency lighting products and systems, such as LED lighting and drivers, allow fire safety legislation requirements to be met, while simultaneously helping to save money longer term and adding to versatility.

There are two main choices for emergency lighting systems. These are the self-contained type having an on board battery in the luminaire, and luminaires that are slaves to a central emergency power system (CPS) in which the batteries are located away from the emergency luminaires. CPS and/or central battery systems are mainly used in medium or large installations where there are many emergency luminaires, or high ambient temperatures, as well as a need for central control.

Integrated CPS systems combined with mains dimmed controlled luminaires is a technology that has evolved to provide still greater benefits for building owners and end-users. Such systems include low-energy LED-based emergency lighting (either self-contained non-maintained, or with central battery systems) combining lighting controls and emergency functions into a single system. Such integrated systems can provide very high design flexibility and save installation time, energy consumption and money, while allowing the creation of a very stylish, unified and yet distinctive architectural appearance.

As LED dimming techniques are further developed and widely used, leading to lower first costs, fully integrated LED dimming controls will become more common in many applications, including new build homes. However, developments are also aimed at designing LED lighting products that can be used with existing dimmers to allow for more retrofitting to existing homes.

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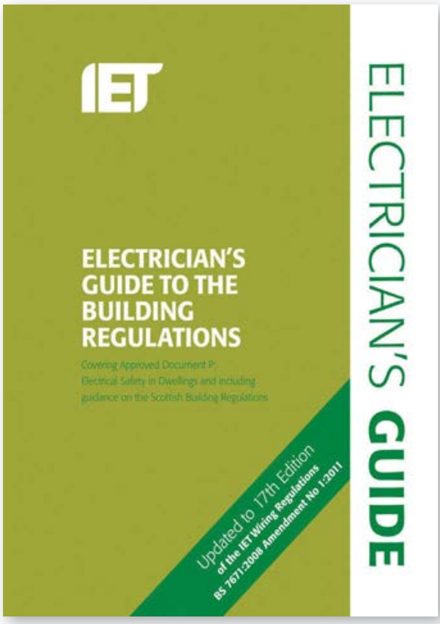

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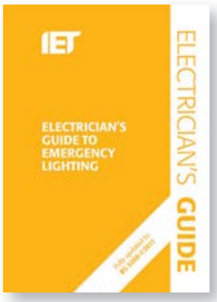

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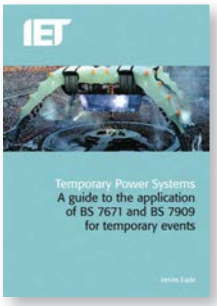

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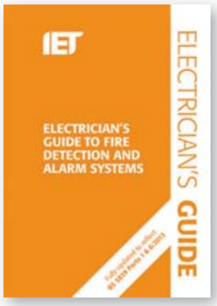

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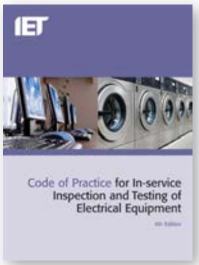

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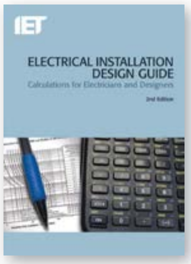

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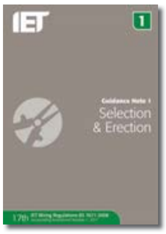

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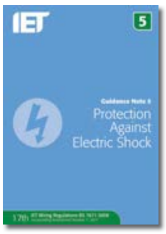

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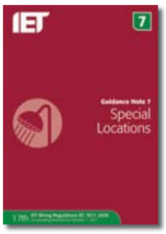

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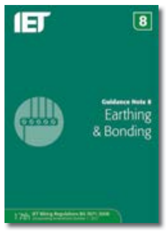

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The TAPS steering group is keen to hear from professionals who wish to help to develop the industry

A BETTER DEAL FOR TECHNICIANS

A study has highlighted the need to promote the careers of technicians within the electrical sector. By Annmarie Dann

IN 2012, a group of partner organisations within the electrical sector began a series of discussions, led by the IET's director of membership and professional development, Michelle Richmond, into the challenges faced at the technician level in their industry. The discussions focused on the perceived shortage of intermediate technical skills along the problems of poor status and recognition.

The partner organisations (the IET, trade union Unite, the Joint Industry Board for the Electrical Contracting Industry, Electrical Contractors' Association, Summitskills and the Engineering Council) formed a technical advisory panel and steering group (TAPS). Supported by sponsorship from the Gatsby Charitable Foundation (Gatsby), TAPS commissioned a research study. Gatsby had previously commissioned research across a number of sectors and confirmed the critical part that technicians play in business. Almost all of these businesses reported difficulties recruiting skilled technicians and many reported that they simply could not recruit the skills needed.

Given that future growth could be constrained by the failure to provide a sustainable supply of technicians, the TAPS team was interested in gaining the insight required to tackle the key technician-related issues faced by the industry.

Its researchers interviewed 268 electricians, contractors and final-year electrical apprentices, along with 30 employers of electricians to gain their thoughts about professionalism, recognition and career pathways. Three important shortcomings were identified:

- **A fragmented industry – confusion exists within the electrical industry regarding competence measurement for electricians, believed by research participants to be caused by the lack of a recognised, common, overarching standard across the electrical industry.**
- **No visible benefit or purpose to career advancement – participants confirmed that career pathways are blurred for electricians and visible benefits associated with career advancement were difficult to identify.**
- **Lack of a nationally recognised competence within the UK – the majority of participants felt strongly about the lack of a recognised 'standard' in the industry, and agreed that an acceptable form of recognised competence would be based on a combined, although not prescriptive, set of key competences that individuals should hold to practice as qualified electricians.**

One indicator of how these shortcomings could be addressed is given by the views of the 200 participants in the survey qualified to Level 3. Nearly half of this group expressed a strong interest in finding out more about a potential electrician/technician membership package/service, and emphasised that their interest would be stronger if such a service involved a range of the key organisations within the electrical industry working together to support such a service/package. One key attraction to a potential package for electricians would be enabling electricians to gain access to relevant career support and guidance to enhance their own development and career plans.

Over half of the employers interviewed stated that they would be open to supporting and funding electrician employees in gaining professional recognition through the Engineering Technician (EngTech) award which the IET is licensed to award.

The TAPS team is keen to build on the results of the findings. It is due to begin discussions to prepare the way for the development of a potential collaborative package/service for this important sector. Qualified electricians, contractors and final-year electrical apprentices are key to ensuring that the next stage of the TAPS team's work is focused. If you would like to become involved in the next stages by providing your input and comments, we would be keen to hear from you, whether as individuals or employers.

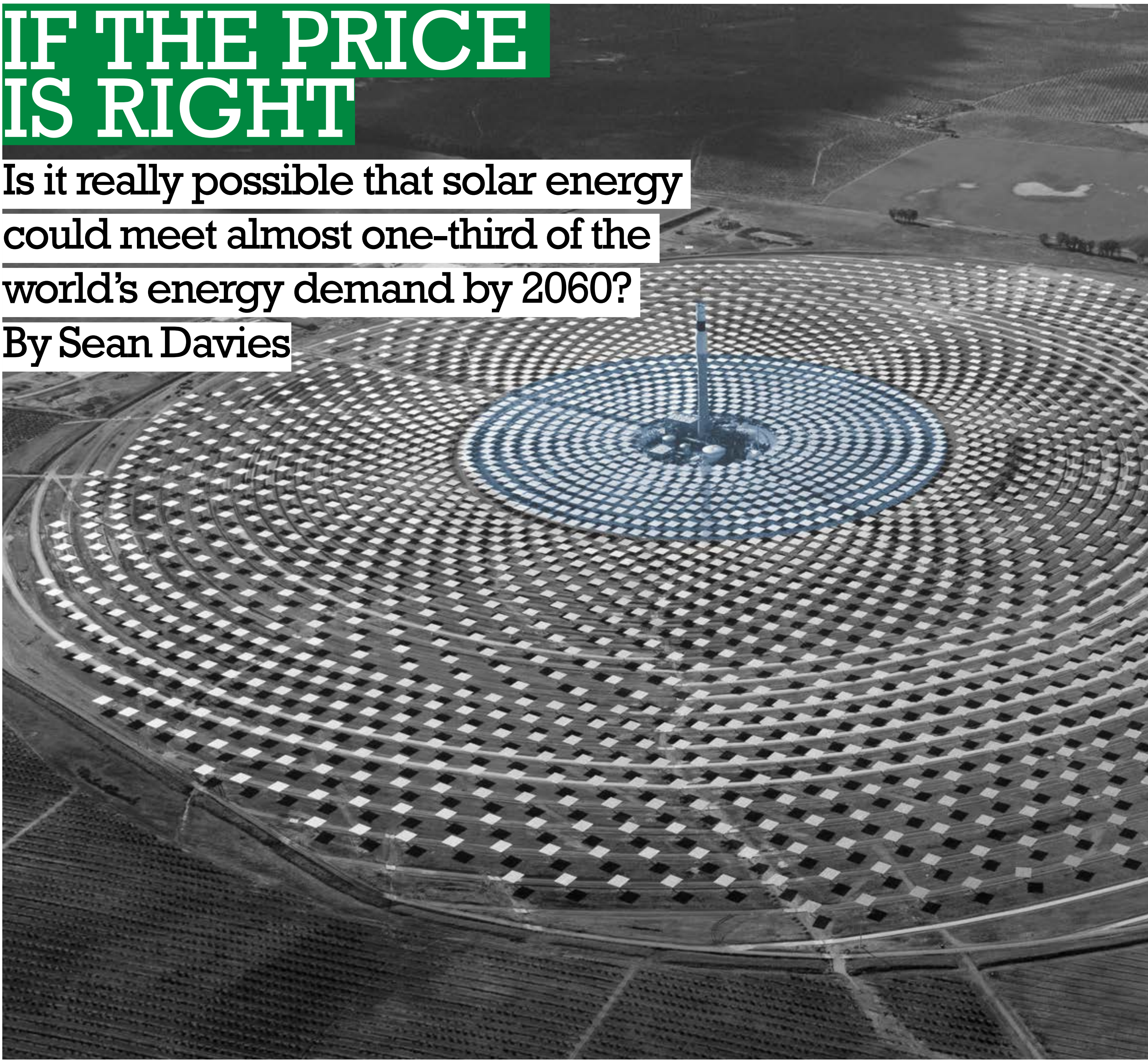
Interested? Please email your name, location, job role, email and telephone contact details to: electechs@theiet.org

Annmarie Dann is IET Research Project Manager.

IF THE PRICE IS RIGHT

Is it really possible that solar energy could meet almost one-third of the world's energy demand by 2060?

By Sean Davies



THERE ARE two main kinds of solar energy – solar photovoltaic (PV) and concentrating solar power (CSP). PV directly converts solar energy into electricity using a PV cell made of a semiconductor material, while CSP devices concentrate energy from the sun's rays to heat a receiver to high temperatures. This heat is transformed first into mechanical energy (by turbines or other engines) and then into electricity – solar thermal electricity (STE).

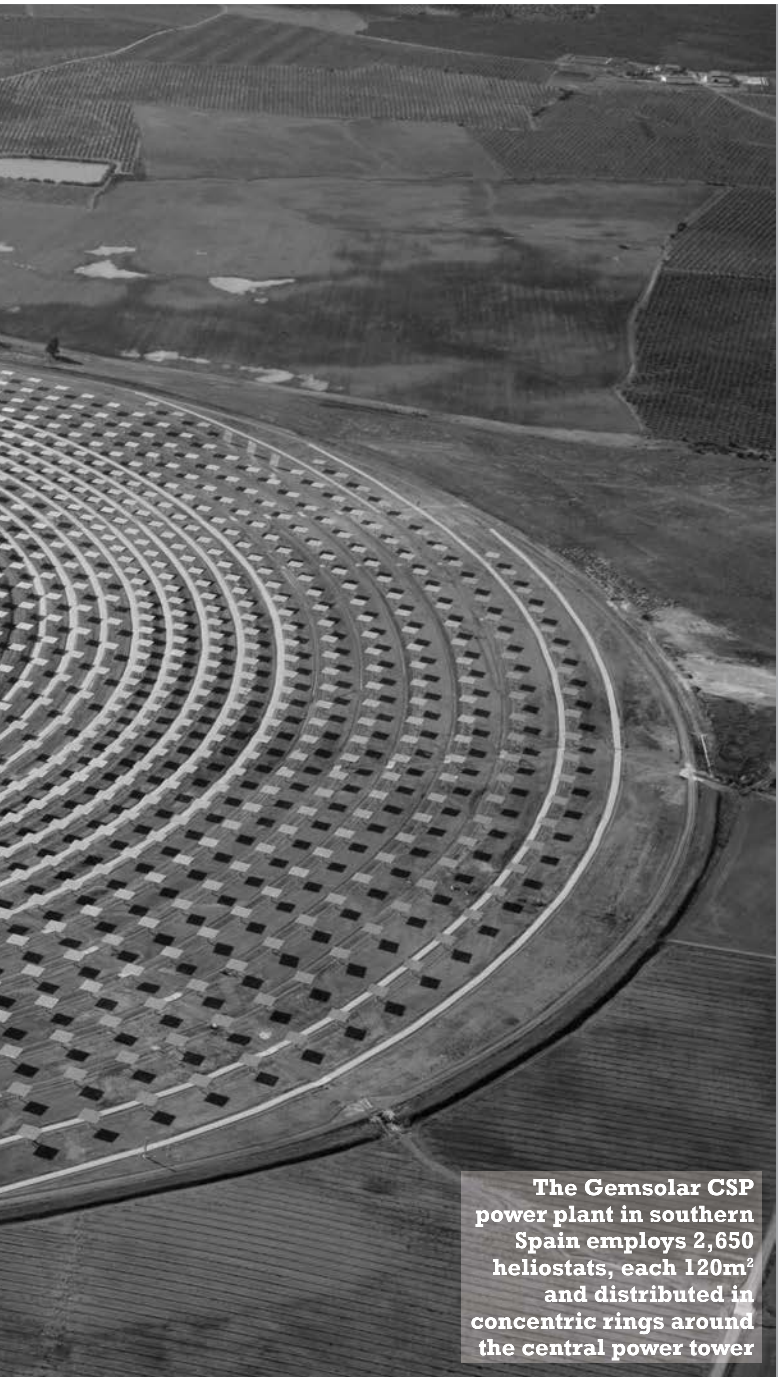
Over the period 2000-11, solar PV was the fastest-growing renewable power technology worldwide. Cumulative installed capacity of solar PV reached roughly 65GW at the end of 2011, up from only 1.5GW in 2000. In 2011, Germany and Italy accounted for over half the global cumulative capacity, followed by Japan, Spain, the United States and China.

In its SunShot strategy the US Department of Energy predicts that when the price of solar electricity reaches about $0.06 per kilowatt-hour over its lifetime, it will be cost-competitive with other non-renewable forms of electricity. This in turn will enable solar-generated power to grow.

The drive to reduce costs encompasses the entire value chain from the efficiency of individual cells to manufacturing costs as well as complementary technologies such as energy storage and effective planning.

Black and dye

One approach is to develop cells that can convert a greater percentage of the



The Gemsolar CSP power plant in southern Spain employs 2,650 heliostats, each 120m² and distributed in concentric rings around the central power tower

sun's spectrum. Around a quarter of the spectrum is made up of infrared radiation, which cannot be converted by standard solar cells. One way to overcome this loss is to use black silicon, a material that absorbs nearly all of the sunlight that hits it, including infrared radiation, and converts it into electricity. Researchers have recently succeeded in doubling their overall efficiency.

"Black silicon is produced by irradiating standard silicon with femtosecond laser pulses under a sulphur-containing atmosphere," says Dr Stefan Kontermann of the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut (HHI). "This structures the surface and integrates sulphur atoms into the silicon lattice, making the treated material appear black." If manufacturers were to equip their solar cells with black silicon, it would significantly boost the cells' efficiency.

By using black silicon, Dr Kontermann and his team at HHI have now managed to double the efficiency of black silicon solar cells. "We achieved that by modifying the shape of the laser pulse we use to irradiate the silicon, enabling us to solve a key problem of black silicon," says Dr Kontermann. In normal silicon, infrared light does not have enough energy to excite the electrons into the conduction band and convert them into electricity, but the sulphur incorporated in black silicon forms a kind of intermediate level.

"You can compare this with climbing a wall," Dr Kontermann adds. "The first time you fail because the wall is too high, but the second time you succeed in two steps by using an intermediate level. However, in sulphur this not only enables electrons to climb the wall, it also works in reverse, enabling electrons from the conduction band to jump back via this intermediate level, which causes electricity to be lost once again.

"By modifying the laser pulse that drives the sulphur atoms into the atomic lattice, researchers can change the positions that these atoms adopt in the lattice and change the height of their levels – in other words, their energy level. We used the laser pulses to alter the embedded sulphur in order to maximise the number of electrons that can climb up while minimising the number that can go back down."

The researchers have already successfully built prototypes of black silicon solar cells and their next step will be to try to merge these cells with commercial technology.

An even more radical approach to delivering solar power would be to dispense with the costly and fragile semiconductor solar panel that uses crystalline silicon. Researchers at the University of Turku believe that they can do this by using flexible, lightweight and inexpensive dyes.

"It is hoped that dye-sensitised solar cells (DSCs) can become a ubiquitous source of energy without the complex and expensive clean-room manufacturing processes associated with current solar panels," Jongyun Moon, researcher at the University of Turku, says.

In a DSC, sunlight hits a layer of the white pigment titanium dioxide, the solar energy absorbed then sucks electrons from dye molecules in a layer beneath this coating, thus generating a flow of electrons and producing a current.

However, Moon suggests that despite the maturity of the silicon technology DSCs could ultimately displace it simply because they are easier and cheaper to manufacture. That said, current DSCs are less efficient than silicon devices and much development work is needed.

Anti-ageing solar

It is not just the high cost of a solar module that is of concern, but also its longevity. Given the high cost of solar power installations it is critical that the modules last as long as possible. Fraunhofer researchers in the US are developing materials to protect solar cells from environmental influences to extend their lives.

Silicone is a promising protective material. It is neither inorganic crystal nor organic polymer, but is related to both. While PV modules have been encapsulated with silicones, until now they were not widely used for laminating solar modules. Lamination is a protective coating that surrounds the fragile silicon wafer. Today, most >

< manufacturers of PV cells use ethylene-vinyl acetate.

To test its properties researchers coated PV cells with liquid silicone. "When the silicone hardens, it encases the cells; the electronic components thus have optimal protection," explains project manager Rafal Mickiewicz.

Prototypes were constructed from the silicone-laminated cells, and tested in a climate chamber at low temperatures and under cyclic loads. Afterwards the module performance was tested with a light flasher.

A comparison of the results with those of conventional solar modules proved that silicone-encased PV modules are more resistant to cyclic loading of the type modules experience in strong winds, in particular at -40°C, giving hope that their useful working life could be extended.

Material concerns

When it comes to utility-scale solar power one of the prime technologies is concentrating solar power. CSP is being widely commercialised and the market has seen about 740MW of generating capacity added between 2007 and the end of 2010.

CSP is expected to grow fast. As of April 2011, another 946MW of capacity was under construction in Spain with total new capacity of 1,789MW expected to be in operation by the end of 2013. A further 1.5GW of parabolic-trough and power-tower plants were under construction in the US, and contracts signed for at least another 6.2GW. Interest is also notable in North Africa and the Middle East, as well as India and China. The global market has been dominated by parabolic-trough plants, which account for 90 per cent of CSP plants.

Unlike some other forms of solar power CSP is largely unrestricted by materials availability. There are, however, some issues that the industry needs to look into soon, like replacing silver in mirrors. In the wake of Chinese export restrictions on rare earth metals, the dependence of some renewable technologies on scarce materials has gained attention. Several players in the PV industry are struggling to get away from excessive use of restricted elements.

A study from Chalmers University of Technology has gone into the details on material issues for CSP, which does indeed seem to be largely unrestricted, viewing the material requirements compared with global reserves. In theory, enough solar plants could be built to cover five times the current global electricity demand.

However, the report also highlights some issues that are likely to pose challenges. Silver, used for reflecting surfaces, will be in short supply in the coming decades even without demand from a booming CSP industry. CSP mirror manufacturers might have to look at other reflective surface materials, such as aluminium, to secure cost competitiveness.

"The prospects for strong growth for CSP over the next few decades seem good, but would cause a stir on the global commodity markets," Dr Erik Pihl of Chalmers University of Technology says.

Solar planning

When it comes to planning a commercial-scale PV plant there are numerous variables to consider including customer specifications, regulations, government subsidy programmes in addition to weather, climate, topography and location. These factors in turn influence the selection and placement of the individual components which include the PV arrays with their solar modules, inverters and wiring, not to mention access roads. Until now, engineers have designed solar-power plants using CAD programs, with every layout separately generated.

Fraunhofer researchers, working with Siemens Energy Photovoltaics, have developed software to aid the process. "Our algorithms provide engineers with several hundred different plant designs in a single operation," ITWM researcher Dr Ingmar Schule explains. "It takes less than a minute of computation time. The only user inputs are parameters such as the topography of the construction site and the module and inverter types that will be used. The user can also change a number of parameters to study the impact on the quality of the planning result."

To evaluate the designed PV power plants, an income calculation is performed that includes a simulation of the weather, the course of the sun throughout the year and the physical module performance including shading effects. With the results of this computation and an estimate of the investment and operating costs, the planning tool can come up with a figure for the LCOE (levelised cost of energy). By comparing the plant with a large number of similar configurations, the planners can investigate the sensitivity of the various parameters to find the right solution.

Solar storage

If solar power is to reach its potential then one piece of the renewable puzzle that needs to be solved is energy storage. With cost-effective storage the fluctuating supply of electricity based on photovoltaics can be stored until the time of consumption. At Karlsruhe Institute of Technology (KIT), several pilot plants of solar cells, small wind-power plants, lithium-ion batteries, and power electronics are under construction to demonstrate how load peaks in the grid can be balanced and what regenerative power supply by an isolated network may look like in the future.

"High-performance batteries on the basis of lithium ions can already be applied reasonably in the grid today," Dr Andreas Gutsch, coordinator of the Competence E project, explains. As stationary storage systems, they can store solar or wind power until it is retrieved by the grid. "When applied correctly, batteries can also balance higher load and production peaks and, hence, make sense from an economic point of view."

Apart from the battery, the key component of the stationary energy storage system is an adapted power-electronics unit that allows the battery to be charged or discharged within two hours. This means that the system can be applied as interim storage for peak load balancing. During times of weak loads, solar energy and wind electricity are fed into the battery. At times of peak load, the energy from the photovoltaics system, wind generator, and battery is fed into the grid.

In spite of the high costs of lithium-ion batteries, this technology may be worthwhile today already, in particular in regions that do not have any stable grids. However, there are projects underway to reduce the cost of the batteries including a joint research project between the University of Southampton and lithium battery technology company REAPsystems.

"Lead acid batteries are used for most photovoltaic systems," MSc Sustainable Energy Technologies student Yue Wu says. "However, as an energy storage device, lithium batteries, especially the LiFePO4 batteries we used, have more favourable characteristics."

Data was collected by connecting a lithium-ion phosphate battery to a photovoltaic system attached to one of the University's buildings, using a specifically designed battery management system.

"The research showed that the lithium battery has an energy efficiency of 95 per cent whereas the lead-acid batteries commonly used today only have around 80 per cent," Wu says. "The weight of the lithium batteries is lower and they have a longer lifespan than >

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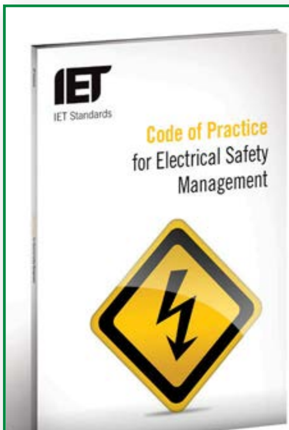

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the lead-acid batteries, reaching up to 1,600 charge/discharge cycles, meaning they would need to be replaced less frequently."

Although the battery will require further testing before being put into commercial photovoltaic systems the research has shown that the LiFePO4 battery has the potential to improve the efficiency of solar power systems and help to reduce the costs of both their installation and upkeep.

Low-cost production

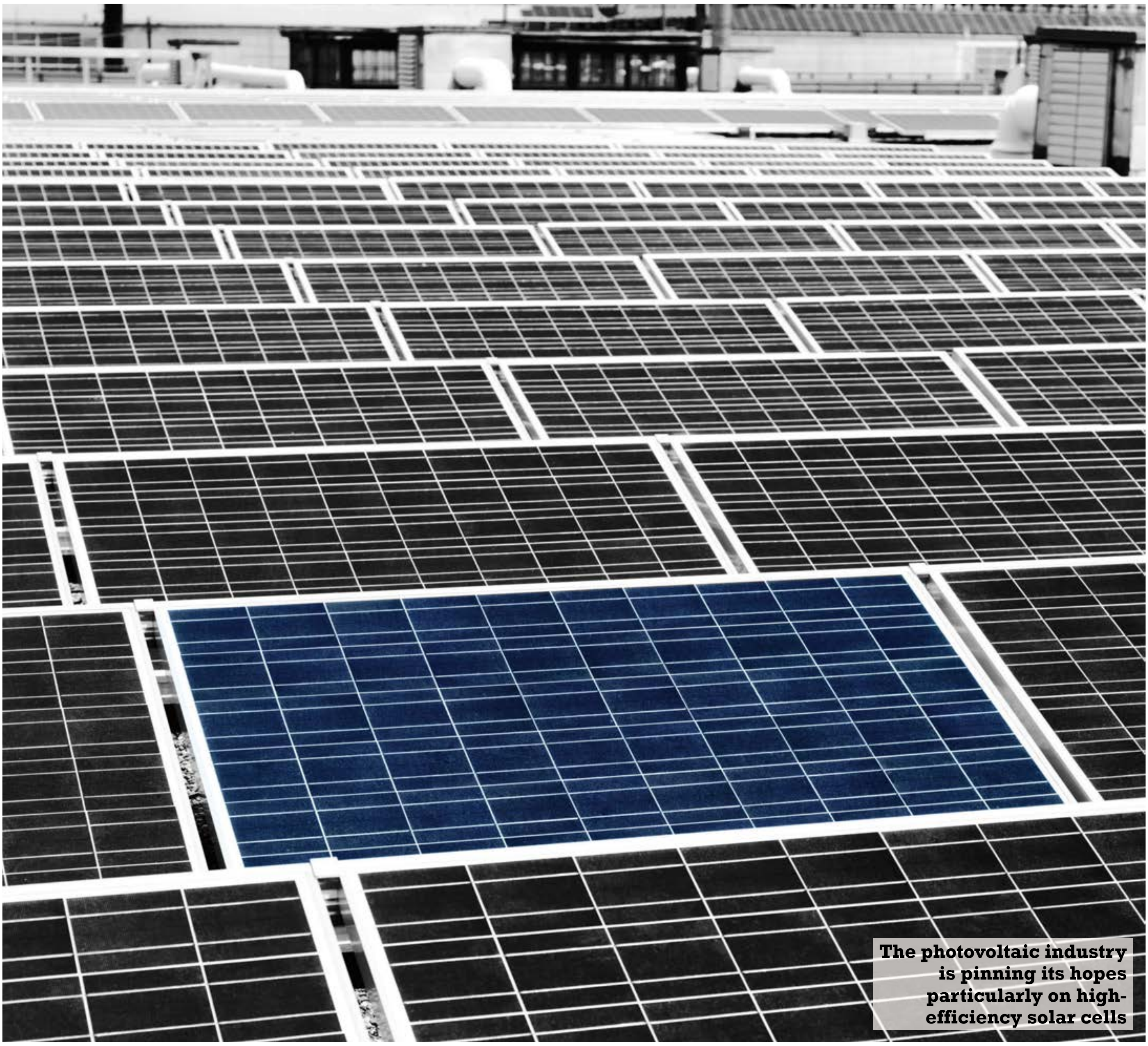
When it comes to economics of solar power it is not just the efficiency of the cells but their manufacturing cost. Asian manufacturers are frequently ahead of the competition in terms of price, which has led to continued research into lowering the manufacturing cost by Western companies.

Researchers at the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig are designing new coating processes and thin-layer systems that, if used, could help to reduce the price of solar cells significantly.

The photovoltaic industry is pinning its hopes particularly on high-efficiency solar cells. These heterojunction with intrinsic thin-layer cells consisting of a crystalline silicon absorber with additional thin layers of silicon. Until now, manufacturers used the plasma chemical vapour deposition process to apply these layers to the substrate.

In this methodology the reaction chamber is filled with silane, and with the crystalline silicon substrate. Plasma activates the gas, thus breaking apart the silicon-hydrogen bonds. The free silicon atoms and the silicon-hydrogen residues settle on the surface of the substrate. But the plasma only activates 10 to 15 per cent of the expensive silane gas; the remaining 85 to 90 per cent are lost, unused. This involves enormous costs.

The researchers at IST have now replaced this process and activate the gas by hot wires. "This way, we can use almost all of the silane gas, so we recover 85 to 90 per cent of the costly gas," Dr Lothar Schafer, department head at IST, explains. "This reduces the overall manufacturing costs of the layers by over 50 per cent. The price of the wire that we need for this process is negligible when compared to the price of the silane."



The photovoltaic industry is pinning its hopes particularly on high-efficiency solar cells

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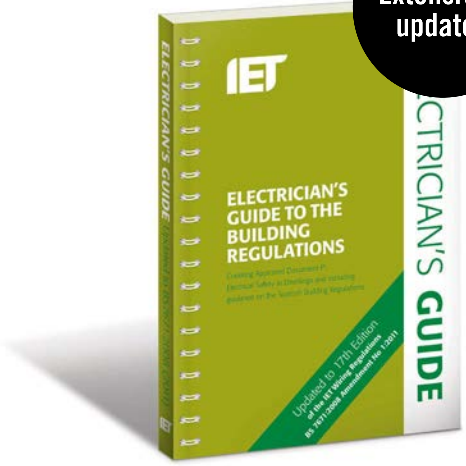
- **Stay up-to-date** with BS 7671:2008(2011) and Approved Document P (April 2013)

Meeting the requirements of the Building Regulations ensures safety for you and your customers.

Update your knowledge of domestic working now:

www.theiet.org/partp-wm

Extensively updated



Tailored industry expertise

Do you know your responsibilities for temporary electrical installations?

This expert new guide explains how to:

- **Stay safe** and avoid the risk of electric shock and fire
- **Observe the law** and fulfil the requirements of the Electricity at Work Regulations 1989 using BS 7671 and BS 7909 as appropriate tools
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