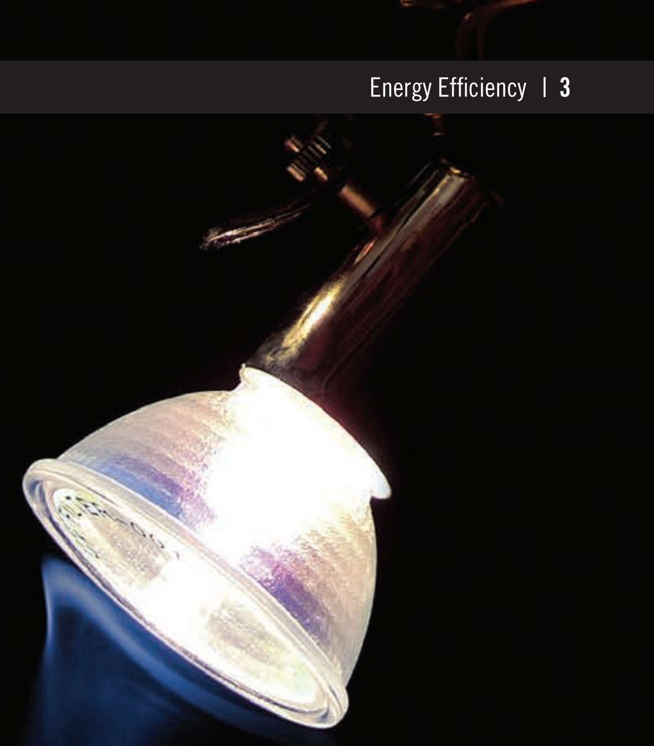

Energy efficiency of low-voltage electrical installations

One new area of possible development within international standards is to integrate requirements for energy efficiency into IEC 60364 (the international standard that the wiring regulations (BS 7671) are based on). In this second article we take a closer look at energy efficiency of low-voltage electrical installations.

By Geoff Cronshaw

In order to make improvements we need to be able to measure the amount of electrical energy consumed and monitor and control energy effectively.

Energy measurement is essential for energy management. Therefore, the design of the electrical distribution system needs to be carried out in such a way that will allow the metering and control of the various electrical loads in an installation.

A further key point when designing a new installation includes determination of the most energy-efficient location of the transformers and switchboards in an installation in order to reduce the electrical losses within the electrical distribution system.

The objective is to locate the transformer and switchboard at the centre of the group of loads they are feeding. Also, in order to have an energy efficient installation, losses in equipment need to be as low as possible.

Maintenance is also important. For example, a lighting installation should be maintained to keep its visual performance within the design limits. The lighting designer will have selected a certain illumination level for the particular activity and presumed a frequency of lamp replacement and a frequency of cleaning. ▶

Photo of Panel mounting and DIN rail mounting KWh meters with pulsed output.

Measurement and control

It is understood that there is no obligation on an electricity supplier to provide any other metering than that required to obtain the basic data to enable tariff charges to be applied.

While this may be adequate for the smaller installation, it does not give sufficient information to allow a larger consumer to allocate costs to various facilities or to control consumption.

Therefore, to be able to measure the amount of electrical energy consumed and monitor and control energy effectively 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 preset limits are exceeded.

Consideration should 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. ▶

Electrical excellence

Wiring Matters is a quarterly publication produced by IET Services Limited, a subsidiary of The Institution of Engineering and Technology (IET), for the IET. Michael Faraday House, Six Hills Way, Stevenage, Herts, SG1 2AY, United Kingdom Tel: +44 (0)1438 313311 Fax: +44 (0)1438 313465. The Institution of Engineering and Technology is registered as a Charity in England & Wales (no 211014) and Scotland (no SC038698). The IET is not as a body responsible for the opinions expressed.

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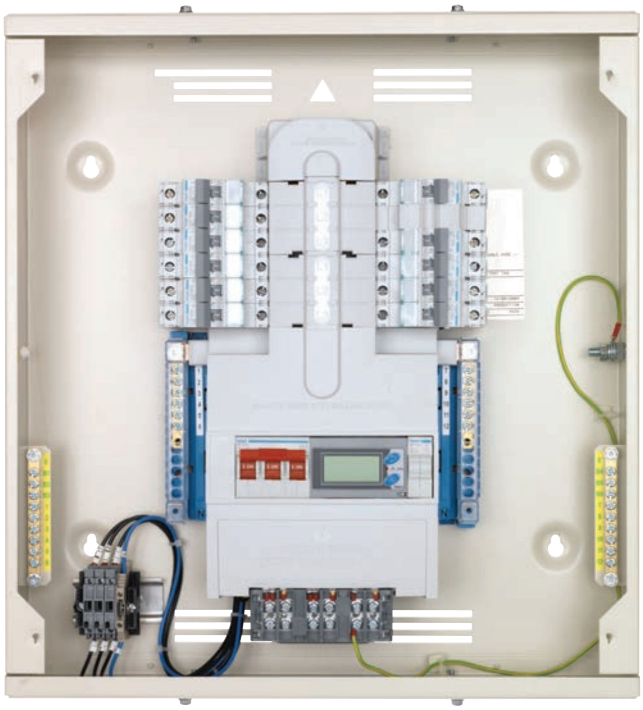
Cooperating Organisations The Institution of Engineering & Technology acknowledges the contribution made by the following organisations in the preparation of this publication: British Electrotechnical & Allied Manufacturers Association Ltd – P D Galbraith, M H Mullins | Department for Communities and Local Government – I Drummond | Electrical Contractors Association – Giuliano Digilio | City & Guilds of London Institute – H R Lovegrove | Electrical Contractors Association of Scotland SELECT – N McGuiness | Health & Safety Executive – K Morton | Electrical Safety Council | ERA Technology Limited – M Coates, A Finney | Consultant - M. Al-Rufaie | Dept of Health - C Holme | British Cables Association – C Reed | Scottish Building Standards Agency | Department for Business, Enterprise and Regulatory Reform | GAMBICA – M Hadley, A. Sedhev | Lighting Association – L Barling
ISSN 1749-978-X

Photo of a Panel mounting and DIN rail mounting multifunction meter. Displays phase sequence, volts, amps, power factor, and system KW, KVAr, PF, frequency, KWh, and KVArh.

Photo of Panel mounted pre wired meter and CT.



Current transformers

Essential to the operation of the meter is the current transformer (CT).

The function of the current transformer, is to transform the high current levels to match the input requirements of the meter. In most cases the input value of the meter is 5A. For example the rating plate of a CT may show 400/5. The high value represents the maximum current of the circuit, and is referred to as the primary value. The low value is referred to as the secondary value.

The accuracy is expressed as a percentage ie class 1 is 1 per cent, class .5 is 0.5 per cent.

Losses in the wiring and transformers

Cables

Appendix 4 of BS 7671 is an informative appendix. The appendix includes tabulated current-carrying capacities for some of the most commonly used cables in the electrical installation industry.

These include single and multicore 70-degree thermoplastic and 90-degree thermosetting insulated cables with copper conductors, 70-degree thermoplastic insulated and sheathed flat cable with protective conductor (copper), a range of armoured cables, and mineral insulated cables. Also a range of cables with aluminium conductors. Tables

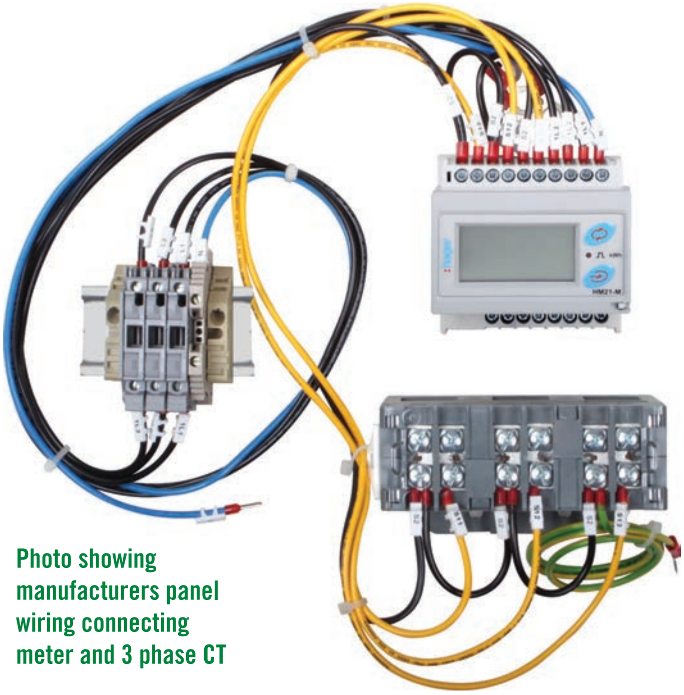


Photo showing manufacturers panel wiring connecting meter and 3 phase CT

4D1A to Tables 4J4A contain the current carrying capacities in amperes for the various types of cable.

The current-carrying capacity of a cable corresponds to the maximum current that can be carried in specified conditions without the conductors exceeding the permissible limit of steady-state temperature for the type of insulation concerned.

The values of current tabulated represent the effective current-carrying capacity only where no rating factor is applicable. Otherwise, the current-carrying capacity corresponds to the tabulated value multiplied by the appropriate factor or factors for ambient temperature, grouping and thermal insulation as well as depth of burial and soil thermal resistivity, for buried cables, as applicable.
Where harmonic currents are present further factors may need to be applied.

Circuits must be designed that are fit for purpose and suitable for the load they are intended to supply. They should be correctly designed in accordance with BS 7671.

Chapter 43 deals with protection against overcurrent and also thermal constraints, Chapter 42 has requirements for protection against thermal effects, Chapter 41 deals with protection against electric shock and gives the disconnection times that must be met whilst Section 525 deals with voltage drop.

However, the procedure generally used for the selection of a cable size leads to the minimum admissible cross-sectional area, which also minimises the initial investment cost of the cable. It does not take into account the cost of the losses that will occur during the life of the cable.

In order to the reduce energy losses as a result of the conductors operating at high temperatures, requires that cable size selection be considered on wider grounds to reduce loses, which is one aspect of energy efficiency being considered.

Transformers

There are basically two types of loss in transformers. These are iron losses and copper losses. Iron losses occur in the magnetic core of the transformer, causing it to heat up. Iron losses can be divided into two components, hysteresis losses, and eddy current losses. In general it is understood that iron losses of a transformer remain constant regardless of load conditions which means that the iron loss on no load will be the same as the iron loss on full load.

Copper losses (load losses) are due to the heating effect of the primary and secondary currents passing through their respective windings.

No-load and load losses in a transformer result in a loss of efficiency. They are the reason for the major running cost of a transformer. They result in heat, which is normally dissipated to the atmosphere. Load losses depend on the load factor (LF). It is understood that in the UK the average industrial load factor on a transformer is probably between 50 and 60 per cent, but where security of supply is of supreme importance the use of two transformers reduces this value to below 50 per cent. Even lower load factors can apply where both load growth and supply security have to be taken into account.

Therefore a key requirement when considering energy efficiency is to decide on the load factor of the transformer at the planning stage in order to run the transformer at its most efficient.

Current-using equipment

Current-using equipment efficiency is based on control of the loads (the right energy at the right time).

Motor control

As mentioned previously in the UK BEAMA have identified that most pump and fan applications are driven by very simple control systems where the motor runs at constant speed and the required flow variation is obtained by using a valve or damper to restrict the flow. This means that the energy consumption falls very little when the flow decreases. At 80 per cent of the nominal flow the energy consumption remains almost the same. ▶

Lighting control sensors providing occupancy and night level detection

◀ A more efficient option is to use a Variable Speed Drive (VSD) to adjust the speed of the motor or fan to deliver the required flow. For fans, savings can be in the region of 50 per cent and for pumps about 30 per cent savings are seen.

Lighting

As mentioned previously, lighting can represent over 35 per cent of energy consumption in buildings depending on the application. Solutions for lighting control may save up to 50 per cent on the electricity compared to a traditional installation. These systems should be flexible and designed for the comfort of the users. The solutions can range from very small and local controls such as occupancy sensors, up to sophisticated customised and centralised solutions that are part of complete building automation systems.

Lighting controls

Automatic lighting controls for residential buildings are easy-to-install devices which are able to detect the presence of people and only switch on lights when required. Lighting controls eliminate wasted energy and save energy simply by switching lights off when not required. Automatic lighting controls for commercial, public and industrial buildings are again easy-to-install devices that are able to automatically switch off lights when no occupants are detected or there are suitable levels of natural light.

When considering the design and installation of lighting controls there are a number of important points to consider. First, it is important to take into account the type of space, how it is used and the amount of daylight available. The type and use of space, together with the type of luminaires installed, will determine the type of sensor and therefore the control used.

Safety is also an important consideration. The operation of automatic lighting controls should not endanger the occupants of the building. This may happen if a sensor switches off all the lighting in a space without daylight. It is therefore important that lighting controls are designed correctly to ensure the safety of occupants and save energy.

Commissioning should be included as an essential part of the installation of lighting controls. Commissioning could include calibrating photoelectric controls, checking that occupancy sensors are working, and setting a suitable delay time for occupancy sensors.

Maintenance

A lighting installation should be maintained to keep its visual performance within the design limits. The designer will have selected a certain illumination level for the particular activity and presumed a frequency of lamp replacement and a frequency of cleaning. The frequency of lamp replacement and cleaning will be appropriate to the environment, including accessibility and the type of luminaire (light fitting). When assessing maintenance requirements the first step is to seek information on the initial design assumptions.

Maintaining a lighting installation as intended will ensure the efficiency of the installation is not degraded. Reduced maintenance may result in reduced operational performance and, in extremes, lead to danger. Maintaining a lighting installation in good order is also important for maintenance of staff morale and provision of a good impression to customers – flickering, failed and discoloured lamps may discourage staff and turn customers away.

There are two aspects to luminaire maintenance: luminaire cleaning and lamp replacement.

Wall and ceiling cleaning

Room lighting levels, as well as depending upon the cleanliness of the luminaires, also depend on the cleanliness of the room, particularly ceilings and walls. This factor is called the room surface maintenance factor (RSMF).

The designer will have assumed a factor for this and may well have assumed a cleaning time for the walls and ceiling. Again, the intervals between the cleaning of floors and ceilings will depend upon the environment and to a lesser degree the nature of the lighting, i.e. whether it is direct or indirect, and on the size of the room.

Indirect lighting reflecting from a ceiling is very dependent ▶

◀ upon the cleanliness of the ceiling or the surface from which the lighting is being reflected, and dirty walls will have a lesser impact on a large room than on a small room.

Lamp replacement

Three factors are particularly important when considering the frequency of lamp replacement. These are:

1. lamp survival factor, LSF (the proportion of lamps still working after a specified burning time);

2. lamp lumen maintenance factor, LLMF (the proportion of the initial light output being maintained after a specified burning time due to deterioration (ageing) of the lamp);

3. cleaning frequency.

Cleaning frequency

It is cost effective to replace lamps when carrying out routine cleaning of the luminaires. As a result, it is almost always sensible to arrange lamp replacement during routine cleaning, but perhaps not at every routine cleaning.

Power-factor correction

A poor power-factor is undesirable for a number of reasons. Power-factor correction technology is used mainly on commercial and industrial installations to restore the power factor to as close to unity as is economically viable.

Low power-factors are caused by reactive power demand of inductive loads such as induction motors and fluorescent lights. A poor power-factor reduces the effective capacity of the electrical supply, since the more reactive power that is carried the less useful power can be carried, also causes losses at transformers, and can cause excessive voltage drops in the supply network and may reduce the life expectancy of electrical equipment.

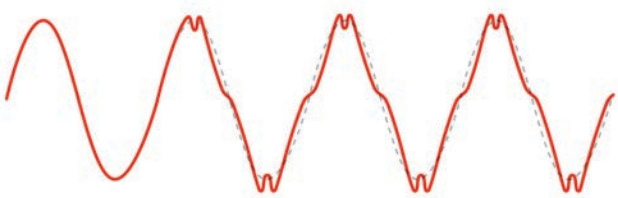
For this reason electricity tariffs encourage the user to maintain a high power-factor (nearly unity) in their electrical installation by penalising a low power-factor. There are a number of ways in which power-factor correction can be provided. The most common way that this can be achieved is by the installation of power factor correction capacitors. These can be installed in bulk at the supply position or at the point of usage on motors, for example. Persons involved in this type of work are recommended to seek advice from specialists on the most economic system for a given installation.

Harmonics

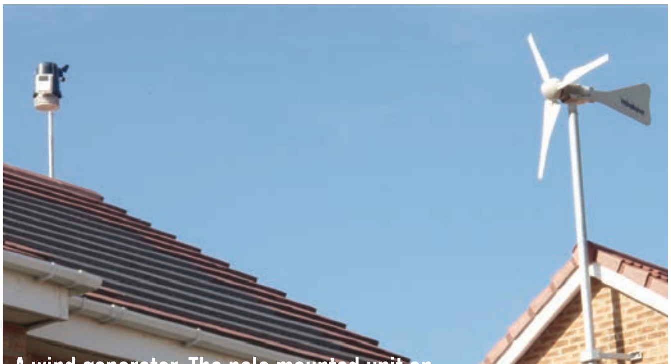
Harmonics are a steady-state disturbance compared with for example short-term transient overvoltages. Harmonics are generally caused by non-linear loads such as switched mode power supplies of computers and discharge lighting see Fig below. Regulations 523.6.1 and 523.6.3 of the 17th edition recognise the effect of triple harmonic currents in the neutral conductor and the need to take account of it. In electrical installations there is a particular problem in three phase circuits.

The third and other triple harmonics combine in the neutral to give a neutral current that has a magnitude equal to the sum of the third harmonic content of each phase. The heating effect of this neutral current could raise the temperature of the cable above its rated value and damage the cable.

Other harmonics can cause problems with electric motors causing the frame temperature to rise consequently reducing the life and efficiency of the motors. With the increased use of switched mode power supplies the resulting harmonic distortion is a major concern. It is therefore important to be able to measure the power quality and where harmonic distortion is found provide a solution to reduce the harmonic distortion.



Harmonics



A wind generator. The pole mounted unit on the roof of the first house is a weather station which can measure wind speed and rate of solar radiation (insolation) and the dark PV tiles are integrated with the red roof tiles.

Renewable energy

On-site renewable energy sources do not of themselves increase the efficiency to the electrical installation but reduce the overall utility network losses as the consumption of the building from the utility is reduced.

There are a wide range of microgeneration technologies including: Solar photovoltaic (PV), wind turbines, Small scale hydro and Micro CHP (Combined heat and power). Microgeneration systems such as solar PV installations should always be carried out by a trained and experienced installer. For example, where the PV panels are roof-mounted the roof must be strong enough to take their weight, especially if the panel is placed on top of existing tiles. It is also important to note that there are mandatory requirements concerning the parallel connection of generators with the supply network.

PV Installation

Section 712 of BS 7671:2008(11) is concerned with the safe installation of solar photovoltaic (PV) power supply systems. A PV system is a collection of interconnected PV cells that turn sunlight directly into electrical energy.

The risks

Modules produce electricity when exposed to daylight. This needs to be taken into account during design, installation, use and maintenance. Also, the electrical installation which incorporates a PV system has a second source of energy which needs to be isolated before starting work. A further risk involves working at height on a roof, for example together with the manual handling associated with a PV installation. Finally, PV installations require expertise in dc wiring and fault protection for d.c. side of the installation.

Scope

Section 712 of BS 7671:2008(2011) applies to the electrical installations of PV power supply systems including systems with a.c. modules. Section 712 does not apply to PV power supply systems which are intended for standalone operation.

The Electricity Safety, Quality and Continuity (Amendment) Regulations 2006

Solar photovoltaic (PV) power supply systems are required to meet the Electricity Safety, Quality and Continuity (Amendment) Regulations 2006 (ESQCR) as they are embedded generators. These are mandatory requirements.

However, where the output does not exceed 16 A per line they are 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;

PV Installations require expertise in d.c. wiring and fault protection for d.c. side of the installation

iii. the equipment must disconnect itself from the distributor's network in the event of a network fault; and
iv. 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 (5 kw) and G59/1', published by the Energy Networks Association (ENA) for larger systems and generators, etc. Further information can be obtained at: www.ena-eng.org.

Protection for safety General requirements

Regulation 712.410.3 requires that PV equipment on the dc side must be considered to be energised, even when the system is disconnected from the a.c. side. This is because modules produce electricity when exposed to daylight. Regulation 712.410.3.6 states that the protective measures of non-conducting location and earth-free local equipotential bonding are not permitted on the d.c. side.

Protective measures

Regulation 712.41 recognises three methods of protection:

- automatic disconnection of supply
- double or reinforced insulation
- extra-low voltage provided by SELV or PELV.

Protection against overcurrent and electromagnetic interference

Regulation 712.433, Regulation 712.434, and Regulation 712.444 are the relevant regulations.

Finally, other regulations in Section 712 of BS 7671:2008(11) include: Regulation 712.512 dealing with operational conditions and external influences, Regulation 712.513 dealing with accessibility, Regulation 712.522 dealing with wiring systems, Regulation 712.537.2.1.1 dealing with isolation, switching and control and Regulation 712.54 deals with earthing arrangements. There are also special requirements for Labelling.

For further information refer to 'BS 7671:2008, Engineering Recommendations G83/1 and G59/1' published by the Energy Networks Association and the Department for Business, Enterprise & Regulatory Reform (BERR).

England and Wales - The Department of Communities and Local Government www.communities.gov.uk

Scotland - The Scottish Building Standards Agency www.sbsa.gov.uk

Note: It is important to consult the Building Regulations in the UK when designing electrical installations. The Building Regulations contain requirements for lighting controls etc. Please note this article is only intended as a brief overview of issues that are being considered at a very early stage and therefore may not become international standards.

Special thanks to Hager for some of the images used.