ELECTRICAL DISTRIBUTION IN BUILDINGS

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SECOND EDITION

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Preface

Although changes take place and are absorbed in the daily routine of business, it is not until one starts to revise a book that one realizes just how much change can take place in a short space of time.

Many changes have occurred since the book was first published in 1987, especially with statutory regulations. The Electricity Supply Regulations of 1937 were replaced with the Electricity Supply Regulations 1988, these in turn were amended by The Electricity Supply (Amendment) Regulations 1990 to take into account the electricity supply industry being privatized. In 1989 two more statutory regulations were introduced, The Low Voltage Electrical Equipment (Safety) Regulations 1989 and The Electricity at Work Regulations 1989, the latter having a profound impact on all persons who use electricity at work. In 1991 we also had the Smoke Detectors Act concerning the installation of smoke detectors in new domestic properties. These were in addition to a host of other legislation.

The beginning of 1993 saw the implementation of the 16th Edition of the IEE Wiring Regulations and it being made into a British Standard to enable British installation rules to be considered by CENELEC. In January 1993 the title of the IEE regulations became 'BS 7671: 1992 Requirements for electrical installations (The IEE Wiring Regulations).' However, in this book the original title 'IEE Wiring Regulations' has been retained.

In addition to the changes brought about by legislation and the 16th Edition of the IEE Wiring Regulations, changes also occurred in British Standards. The British Standards for HRC fuses were changed, as were the standards for emergency lighting and protection of structures against lightning to name but a few.

All this has meant a considerable amount of rewriting has had to be carried out to bring the book up-to-date, but I was pleased that I was asked to revise the book since I knew Dennis Poole and in particular John Vollborth, who I became friendly with whilst I was lecturing on the wiring regulations for the IEE.

The philosophy behind the original book has not changed and the original chapter titles have been retained.

Trevor E. Marks
1993

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Chapter 1
Electricity Supplies

Unless an installation is provided with a suitable and adequate supply, whether from private generation or a regional electricity company, an impossible situation is almost certain to arise as the consumer may find that he is limited with regard to the maximum loads that he can connect or the type of equipment that he can use, particularly with commercial and industrial installations. In domestic premises, unless they are situated in extremely isolated locations, it is unusual for there to be problems. Exceptions would be where the regional electricity company has no adjacent distribution system and has to install, for example, an 11 kV light-line extension and pole-mounted transformer equipment.

In all cases, however, it is essential to apply to the appropriate electricity supplier in good time.

Agreement with regional electricity company

As the majority of electrical installations require a supply from an electricity supplier which, in the UK, means one or other of the regional electricity companies, one of the most important – but too often one of the last to be considered – requirements is the negotiation of a suitable service and the most advantageous tariff for the consumer with the appropriate supplier.

Although the British Isles has probably one of the most effective supply networks in the world, experienced engineers are aware that there may be limitations on the additional loads imposed by new buildings and extensions on existing installations. However, it is too frequently taken for granted that, somehow or other, the regional electricity company will solve any problem if or when it arises, without difficulty. It should be realized that, at the least, any work necessitated by the supplier may impose unanticipated costs while, in very rare cases, it may prove completely impossible to provide a suitable supply at all. This is even more probable in certain areas of the world, particularly where the supply is weak or the load too much for the network. It is, therefore, essential that an approach be made to the electricity supplier at the conceptual stage of a completely new project and, at the latest, before connection of any additional loads. In the latter case, it should be remembered that, in the UK at least, the regional electricity company may disconnect any installation completely if the consumer's installation is not constructed, installed, protected and used so as to prevent danger and not to cause interference with the supplier's system or the supply to other consumers.

Additionally, in order to comply with the 16th Edition of the IEE Wiring Regulations it is not possible to commence the design of a new installation until both the prospective fault level at the origin of supply and the external impedance have been obtained, both being factors which only the regional electricity company can provide, before the supply is available.

Prior to entering into discussion with a regional electricity company's representative, it is of benefit to have assessed the probable maximum demand, load factor (i.e., average load divided by peak load) and consumption of the proposed installation. However, when dealing with a project of any size, it is usual to find that there will be both commercial and mains development engineers involved who have a very wide experience and are prepared to offer their knowledge to a prospective consumer.

The UK electricity supply industry comprises some fourteen regional, individual, private companies who distribute most of the electricity to the consumer. Although each of these private companies can and do generate electricity the bulk generation of electricity is carried out by Power Gen, National Power, Nuclear Electric and Scottish Generators. The electricity generated being distributed into each region by the National Grid Company, which is owned by the regional electricity companies.

Figure 1.1 shows the geographical areas of the UK regional electricity companies.

Tariffs

Large consumers of electricity can negotiate for their own individual supply of electricity direct with one of the generating companies, who are responsible for bulk generation, or with one of the regional electricity companies.

The regional electricity companies are not confined to their own geographical area and can trade anywhere. For instance, NORWEB plc can trade in the area covered by East Midlands Electricity, they can even supply customers in the East Midlands with electricity, although for the moment, the customer must have a certain maximum demand before he can start to negotiate with the suppliers of electricity.

Fig. 1.1 UK regional electricity companies.

As far as tariffs are concerned the general pattern between the regional electricity companies presents three options to the prospective commercial and industrial consumer, as follows:

(1) General purpose tariff.
(2) Low voltage maximum demand.
(3) High voltage maximum demand.

The above may not always be the case, especially since privatization of the regional electricity companies, whose commercial engineer should be consulted.

General purpose tariff

This is for the relatively small installation and consists of a quarterly standing charge plus a unit charge (applicable to lighting, heating and power) which may be on a reducing scale as the number of units consumed increases. An additional possibility that may be available is a reduction in the charge for units metered during a night-time and/or weekend period.

Low voltage maximum demand tariff

This may consist of several component charges covering, for example, a monthly charge, availability, actual maximum demand, units consumed and a fuel adjustment. While the latter is related to Platt's oilgram price of 1% sulphur heavy fuel oil and, therefore, is not controllable by the regional electricity companies, the other components may also be subjected to variations governed by the suppliers' commercial requirements and are clarified as follows.

Availability

The maximum demand agreed between the consumer and the electricity supplier becomes the authorized supply capacity and for supplies up to 100 kVA the supply is usually agreed in blocks of 5 kVA. Supplies larger than 100 kVA are agreed in larger blocks.

The availability charge is made on the agreed authorized supply capacity unless this value is exceeded, in which case it is made on the higher value for the next 12 months. If the higher value of maximum demand is exceeded before the 12 months has expired the charge is then made on the new higher demand and the 12-month period then starts again. For example, if the authorized supply capacity was 50 kVA then the availability charge would be made on 50 kVA each month, if the maximum demand (which is the authorized supply capacity) is increased to 53 kVA just for the month of March, then the charge each month would be made on 55 kVA until April the following year, if, however, the demand went up to 58 kVA just for the month of June then the charge each month would be made on 60 kVA until July the following year. If after June the demand fell back and did not exceed the original 50 kVa for the remaining months, then in July the following year the charge would fall back to that levied on 50 kVA.

It can be seen that the consumer who occasionally exceeds his authorized supply capacity is penalized for the following 12 months. If the authorized supply capacity was exceeded every month then the supplier would negotiate a new contract, which may involve the consumer in a capital contribution if the excess demand cannot be permanently met from the existing local network.

Maximum demand

The charge is made for the maximum demand per month for each kVA of monthly maximum demand as follows:

March to October	Nil
December and January	£x per kVA
November and February	£y per kVA

The charges are highest in the months when electricity is in peak demand. Increased demand during the winter months would require capital costs of providing the capacity which would then be unused during the remainder of the year. The actual months and charges can vary from region to region.

Modifications are also available to these tariffs for those consumers whose highest demands occur outside the hours of 7.00 AM to 8.0 PM on weekdays or for those consumers whose highest demands occur between midnight and 8.00 AM each day.

Unit charge

This is related to the actual kWh metered, with units metered during a night-time period being considerably lower in price than daytime units. The lower price may be of the order of 40 to 50% of the higher.

High voltage maximum demand tariff

This tariff is worked out in the same way as the low voltage maximum demand tariff with the difference, of course, that the metering is effected on the high voltage side of the supply. Because of this, any costs incurred by the consumer in the transformation of the supply voltage are also metered and charged. Taking the supply at high voltage usually results in slight reductions in the various component charges relative to the low voltage maximum demand tariff, but it is wise to ensure that low-loss transformers are utilized where available.

Additionally, should this tariff be applicable, the consumer is responsible for the purchase and installation of the switchgear and transformers required, equipment which entails the employment of staff who have had adequate training and experience in the operation and maintenance of this type of equipment. Alternatively, a maintenance contract with the regional electricity company can be negotiated.

Metering

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 installations, it does not give sufficient information to allow a larger consumer to allocate costs to his various facilities or to control consumption. Consequently, it may be advisable, perhaps even essential, for the prospective consumer to take such possible requirements into consideration in the planning stages and to have the necessary metering equipment built into his switchboards. Although this will increase the initial cost of the switchgear, it will prove more economical than having to add metering at a later date.

Operating cost control

Maximum demand limitation

Although electricity charges on flat-rate tariffs (domestic) are not affected by maximum demand penalties, this is not the case with maximum demand tariffs and, as explained earlier the resulting charge may constitute a large proportion of each electricity account. Consequently, it is to the benefit of the consumer to ensure that the maximum demand is kept to the lowest possible level.

In many cases the highest maximum demands are recorded during start-up periods – first thing in the morning, after the midday break or when canteen staff commence operations – and, therefore, it is to the consumer's advantage to ensure, as far as possible, that heavy machinery, or machinery which demands a high starting peak, is adequately monitored so that sequence start-up can be adopted. Where large groups of machines are supplied from one source this may be accomplished easily, and relatively economically, by automatic means built into switchboards or motor control centres but, alternatively, much success can be obtained by adequate training and good housekeeping.

Power factor correction

Maximum demand in commercial and industrial premises is generally measured in kVA and, therefore, the effects of a low power factor may be considerable. Not only will this affect the maximum demand charge but also, due to the higher than necessary currents, it will increase running costs as the I^2R (copper) losses will be greater than necessary. It is advisable, therefore, for consideration to be given to the installation of power factor correction equipment. This is not applicable to domestic installations as the tariffs do not include power factor clauses.

While, on very large factory installations, correction may be provided by means of over-excited synchronous motors, the majority of consumers should confine their requirements to static equipment with, possibly, automatic control for switching capacitors in or out in accordance with the situation or, alternatively, by installing correction equipment at the point of usage, e.g. on motors. This latter is probably the most economical method from the point of view of capital cost and, as a capacitor will only correct power factor on the supply side, will have the maximum effect on the whole of an installation. The disadvantage is that correction only applies to the drive to which it is connected and, therefore, has to be repeated on similar machines. As the life of such equipment is of the order of 25 years, this should not present any serious maintenance problems. For safety capacitors must contain discharge resistors.

Examples of tariff benefits obtained from power factor correction are published in numerous textbooks, in capacitor manufacturers' catalogues and similar literature. However, as installations and usage vary so much, the consumer would be well advised to seek help from supply specialists.

While, logically, the greater benefits are to be obtained from a power factor of unity, it should be noted that the optimum for practical purposes is approximately 0.97. Below this level, the capacitive correction required is virtually proportional to the improvement gained while, above it, the capital cost is unlikely to be recovered within an acceptably economical period of time.

A diagram such as Fig. 1.2, if drawn to scale, is one method used to calculate the amount of power factor correction required to provide improvement. AB represents kW, AD is kVA at a power factor of 0.85, AC is kVA at 0.97 power factor and BCD the kVAr. Therefore CD gives the reactive capacity (kVAr) to correct from 0.85 to 0.97 and BD from 0.85 to unity. The geometrical angles of lag are also shown on the diagram.

The reader will be familiar with this and also with the mathematical

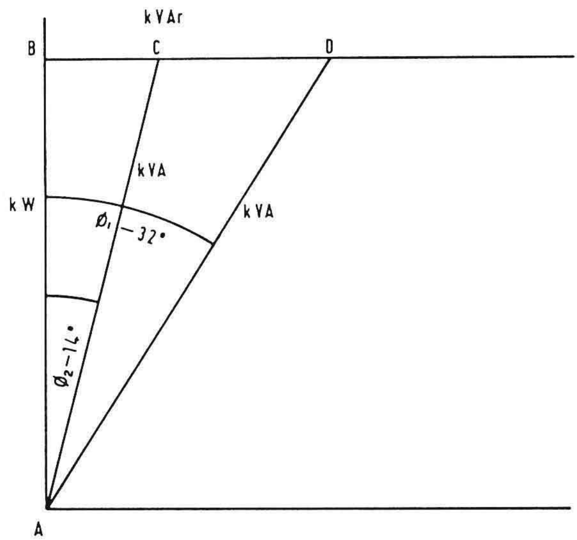

Fig. 1.2 Phase angles and power factor.

method; however, an example of the latter follows, assuming a true power of 100 kW with the above power factors.

kVA = AD = 100/0.85 = 117.6: AC = 100/0.97 = 103.1 kVA

As BD = tan∠BAD × AB, from trigonometrical tables obtain the tangents of the angles represented by cos 0.85 and 0.97, i.e. 0.63 and 0.25. Therefore:

BD = 100 × 0.63 kVAr = 63 kVAr
BC = 100 × 0.25 kVAr = 25 kVAr

From the above, 63 – 25 = 38 kVAr will be required to correct from 0.85 to 0.97 and a further 25 kVAr to bring the power factor to unity.

As power factor correction capacitors are manufactured in standard ratings, which are banked to provide the required capacity, and the combinations are not infinitely variable, it is impractical to use mathematically precise quantities for the calculations and, therefore, one or two decimal places are adequate for a working situation.

As already mentioned, a low power factor causes unnecessarily high currents for a given true power which increases copper losses and may, in fact, require larger cables to be installed than would normally be used. However, the different regional electricity companies are not consistent in their choice of preferred power factor at which penalties are imposed,