

SELECTION OF FINAL CIRCUIT PROTECTION

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Executive summary

The selection of devices for final circuit protection in electrical installations is no longer as simple as it used to be. In modern installations, it's necessary to decide where to use miniature circuit breakers (MCBs), where to use residual current circuit breakers (RCCBs) and where residual current breakers with overcurrent protection (RCBOs) would be the best choice. And that's not the only decision to be made.

All of the devices mentioned are available in several versions that have different characteristics. It is essential to match the characteristic of the device chosen with the application, a task that has now been complicated by the increasing number of "electronic" loads, such as televisions, computers and even some forms of lighting, and by the spread of "green energy" installations, such as solar photovoltaic (PV) systems.

This white paper first discusses the configuration of modern final circuit distribution and protection systems, concentrating particularly on consumer units, and also provides guidance on the selection of protection devices that are used in those systems. Note that this paper does not specifically cover moulded case circuit breakers (MCCBs), which are typically used for final circuit protection only in the largest installations.

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Consumer Units

Often still referred to as 'fuse boxes', today, a very small number of new consumer unit installations actually have any fuses fitted at all. By far the most common devices fitted are MCB's and RCD's along with a growing demand for additional functions including timers, contactors, transformers and energy meters.

The configuration of consumer units is, for the most part, guided by the requirements laid down in the IET Wiring Regulations. The introduction of the 17th Edition of these regulations in July 2008 heralded a big change, as this edition places much greater emphasis on the use of 30mA residual current (earth leakage) devices for circuits. In fact, the 17th Edition identifies five important areas for consideration:

1. Socket outlets not exceeding 20A for general use must be provided with additional protection by means of 30mA RCD's (Reg. 411.3.3)
2. All circuits in locations containing a bath or shower including low voltage circuits must be provided with additional protection by means of 30mA RCD's (Reg. 701.411.3.3)
3. All unprotected cables buried less than 50mm deep in a wall, ceiling or floor must be provided with additional protection by means of 30mA RCD's (Regs. 522.6.100 -103)
4. The installation should be sub divided to reduce risk, inconvenience and minimise nuisance tripping etc. as detailed in (Reg. 314.1)
5. Separate circuits should be provided for circuits that need to be separately controlled to ensure that they are not affected by the failure of other circuits.(Reg. 314.2).

Based on these considerations, the configuration of the consumer unit and the design of the wiring scheme can be determined.

There are a number of alternative consumer unit solutions that can be used to enable a fully compliant installation to be achieved. Key to any compliant consumer unit configuration is the provision of 30mA RCD protection on multiple circuits within the unit and this can be achieved by the fitting of two or more double pole RCCBs or individual RCBOs, or a combination of the two.

The most comprehensive final circuit protection available can be provided by a consumer unit which has each and every outgoing circuit protected by a separate 30mA RCBO. This provides overload and short circuit protection as well as residual current earth fault protection. Although this is the most expensive consumer unit option, this type of arrangement will fully address all of the points detailed above.

The most popular and cost effective choice of circuit protection used is a much simpler isolator-controlled dual RCCB consumer unit. This allows the individual outgoing MCB protected circuits to be divided across two separate 30mA double pole RCCB zones ensuring that, for example, the upstairs power is fed from one RCCB and the lighting is fed from another in order to comply with the first four key areas detailed above.

A composite unit incorporating two or more RCCB protected zones, as mentioned above, but with the addition of some individual ways fed directly off the main isolator switch and used to power individual circuits via an MCB or an RCBO, can be configured to provide compliance with both the first four key areas, as well as point five where separate circuit control is required.

A consumer unit with a single RCCB main incomer could not be used on its own to provide a compliant installation as it would be unable to provide compliance with points four or five, although it could form part of a compliant installation if used with other switchgear components.

Often, reference is made to '17th Edition consumer units', but it is important to remember that there is actually no such thing. It is the electrical installation that is required to comply with the IET wiring regulations, using components such as consumer units which should comply with the current product standards. Almost any consumer unit can be used in a 17th Edition installation; it is the way it is applied that determines whether the installation is compliant or not.

Circuit Protection Devices

Traditionally, fuses were the main devices chosen for final circuit protection, up until the 1970's when circuit breaker technology started to become dominant. Today, the principle circuit protection devices are: Miniature Circuit Breakers (MCBs), Residual Current Circuit Breakers (RCCBs) and Residual Current Circuit Breakers with Overcurrent protection (RCBOs).

Protection Devices - MCBs

MCBs provide overcurrent and short-circuit protection only and are unable to detect residual current (earth leakage current) unless it is large enough to be classed as an overload or short circuit. In many applications therefore, RCBOs are a better option, but MCBs are still the most widely used devices not least in older installations. Also, there are some instances where it may be preferable to use an MCB in conjunction with a separate RCCB rather than an RCBO, as the use of separate devices can give a wider choice of protection characteristics.

In those cases where MCBs have been selected as the most appropriate protection device, the next step is to decide on the type of MCB to use. BS EN 60898 defines several types of MCB according to their operating characteristic. The most common MCB characteristics are Types B, C and D, which cover the majority of commonly encountered applications. These have more recently been joined by Type K characteristics which offer improved protection in certain applications. In consumer unit applications it is rare to see anything other than Type B MCBs used, with the occasional use of Type C devices on high inrush circuits such as some lighting loads.

There are also other specialised types, but these are rarely, if ever, encountered in normal installation work, and are not considered in this paper. Let's examine the most common MCB characteristics in a little more detail:

Type B MCBs react quickly to overloads, and are built to trip when the current passing through them is between 3 and 4.5 times the normal full load current. They are suitable for protecting incandescent lighting and socket-outlet circuits in domestic and commercial environments, where there is little risk of current surges of a magnitude that could cause the MCB to trip.

Type C MCBs react more slowly, and are recommended for applications involving inductive loads with high inrush currents, such as fluorescent lighting installations. Type C MCBs are built to trip at between 5 and 10 times the normal full load current.

Type D MCBs are slower still, and are set to trip at between 10 and 20 times normal full load current. They are recommended only for circuits with very high inrush currents, such as those feeding transformers and welding machines. Note, however, that MCBs with Type K characteristics may provide better protection in some applications of this type.

Type K MCBs are designed to trip at between 8 and 12 times normal full load current, placing them between the traditional Type C and Type D breakers. In most cases, they allow improved cable

protection to be provided in circuits that include motors, capacitors and transformers, where it would previously have been necessary to use Type D devices. This enhanced protection is achieved without increasing the risk of nuisance tripping.

When selecting MCBs, it is essential to remember that their primary function is to quickly disconnect a fault current to protect cables and equipment downstream of the device as well as to protect personnel from electric shock. This means that devices must be chosen with ratings appropriate to the application and size of cables in use. Detailed guidance on how to do this is given in the IET Wiring Regulations.

Note also that Type B and Type C MCBs can normally be selected to provide tripping times that will give adequate cable protection, but this can be more difficult with Type D and, in some cases, with Type K devices, where a lower loop impedance (Z_s) may be needed to achieve the tripping time prescribed in the Wiring Regulations.

A further essential feature of MCBs that must be considered is breaking capacity. This must always be greater than the prospective short-circuit current (PSCC) at the point where the MCB is to be installed, or there is a risk that the device will be unable to clear faults safely.

In practice, it's not usually difficult to satisfy this requirement, as part of the routine testing of electrical installations, which is required by the IET Wiring Regulations, involves measuring the source impedance of the supply, from which the PSCC can be calculated. In fact, many types of installation test set perform this calculation automatically.

MCBs with a breaking capacity of 6 kA are very widely used and are usually chosen for domestic applications. Devices with breaking capacities of 10 kA and even 25 kA are normally used in commercial and industrial applications due to the inevitable higher fault levels associated with these installations.

Protection Devices – RCCBs

Intended principally to minimise the risk of injury from electric shock, RCCBs provide protection against residual (earth leakage) currents only, and are not sensitive to overloads or short circuits. For this reason, they must never be used as the sole protection device for a circuit; circuits with RCCB protection must always include separate protection against overloads and short circuits. This is most often an MCB, but it could, for example, be a fuse.

Like MCBs, RCCBs are available in various different types that are designated by letters. This is a potential source of confusion so it's worth remembering that a Type B MCB, for example, is not related to a Type B RCCB. The types of RCCB most likely to be encountered are Type AC, Type A, Type B, Type B+ and Type S as detailed below:

Type AC RCCBs are sensitive to ac currents and are suitable for most domestic and commercial applications.

Type A RCCBs provide additional protection compared with Type AC devices, as they are sensitive not only to ac currents but also to pulsating dc currents. Type A devices should be used in preference to Type AC in applications where there are a lot of "electronic" loads, such as computer equipment or lighting systems with electronic ballasts.

Type B RCCBs are sensitive to ac, pulsating ac and steady dc leakage currents. This type may be required for use in photovoltaic (PV) solar energy installations because the PV panels produce a dc

output and some types of fault can result in the leakage of dc currents to earth. This will however depend upon the inverter used in the installation.

Type B+ RCCBs are similar to Type B, but respond to ac leakage currents over a wider frequency range, which is useful in some specialised applications.

It's worth noting that Type B and Type B+ devices can be used wherever a Type AC or Type A device is specified, as they provide the same functionality as these types and more.

Type S RCCBs are selective devices intended for use where circuits include more than one RCCB. For example, an installation could include an upstream RCCB to provide protection for several downstream circuits, some of which also have their own RCCB or RCBO. If an earth fault occurs on one of the downstream circuits with an RCCB or RCBO, this device should trip rather than the upstream RCCB. Using a Type S RCCB for the upstream device will provide the necessary selectivity.

RCCBs are offered with various sensitivity ratings. In theory, a more sensitive device (that is, one with a lower trip current) will provide more effective protection against the risk of electric shock, but in practice it will also be more prone to “nuisance tripping” – tripping when no significant hazard is present. Guidance on choosing devices with appropriate sensitivity is provided in the IET Wiring Regulations, which should always be consulted. For most domestic and small-scale commercial applications, however, 30 mA devices are used.

Protection Devices – RCBOs

RCBOs are devices that combine the functions of an MCB and an RCCB in a single device. They therefore provide overload, short-circuit and residual current (earth fault) protection, and are normally used as the only protective device in the circuit.

In principle, it would be possible to produce a huge range of RCBOs with different combinations of MCB and RCCB characteristics. In practice, manufacturers limit themselves to the most commonly needed combinations. These typically include a Type B or Type C MCB characteristic, combined with either a Type AC or Type A RCCB characteristic.

Where other combinations are needed, it usually means that an RCBO can't be used and the necessary protection must be provided by using a separate MCB and RCCB. It is worth noting, however, that field-fittable residual current pods are still available, which can be used to convert some older MCB's into RCBO's thus allowing the simple upgrade of existing installations.

A recent development worthy of note is the introduction of so-called compact RCBOs. In the past, RCBOs were invariably larger – usually much taller – than ordinary MCBs. This meant that they took up more space in consumer units and distribution boards, making it more difficult to wire. The new compact RCBOs are not much larger than an ordinary MCB and therefore make the installation process a lot easier. Compact RCBOs are available with the same combinations of characteristics as standard RCBOs.

The current rating, breaking capacity and residual current sensitivity of RCBOs are chosen in exactly the same way as they are for separate MCBs and RCCBs.

Conclusion

The wide range of options available often makes the task of choosing the best form of final circuit protection for a given application seem complicated and daunting. This white paper has provided guidance designed to make the task easier by giving a concise overview of the main types of protection product currently available and their principal applications.

It must be borne in mind, however, that this paper is not an exhaustive guide to protection device selection. When specifying, designing or installing protection systems, direct reference should always be made to the relevant standards and regulations to ensure that full compliance is achieved.

In cases where further guidance or advice is needed, Eaton will be pleased to help. The company is one of the world's largest suppliers of electrical distribution and protection products, and it is always ready to apply its unrivalled expertise in this field to support and assist its customers.

References

- **The IET Wiring Regulations (BS 7671)** set the standards for electrical installations in the UK, and should always be consulted when designing, specifying or working on these installations.
- **BS EN 60898-2:2006** is the British Standard that covers circuit breakers for overcurrent protection in household and similar installations.
- **PD IEC/TR 62350:2006** provides guidance for the correct use of residual current-operated protective devices (RCCBs) for household and similar uses.

About Eaton

Eaton's electrical business is a global leader with expertise in power distribution and circuit protection; backup power protection; control and automation; lighting and security; structural solutions and wiring devices; solutions for harsh and hazardous environments; and engineering services. Eaton is positioned through its global solutions to answer today's most critical electrical power management challenges.

Eaton is a power management company providing energy-efficient solutions that help our customers effectively manage electrical, hydraulic and mechanical power. A global technology leader, Eaton acquired Cooper Industries plc in November 2012. The 2012 revenue of the combined companies was \$21.8 billion on a pro forma basis. Eaton has approximately 102,000 employees and sells products to customers in more than 175 countries. For more information, visit www.eaton.eu.

About the author

Phil Williams is product marketing manager responsible for home automation and residential switchgear products, including consumer units and their associated devices. His career in the electrical sector started at GEC English Electric Fusegear in 1975, and he has a BSc in Electrical and Electronic Engineering. Phil's previous experience includes working for GEC Alsthom and GE Power Controls as the European product marketing manager for Fusegear.

In his current role with Eaton, Phil supports the sales team on all aspects of the residential switchgear, wiring accessories and lighting controls business in the UK. He is also responsible for driving the development of the Eaton home automation product offering for the smart homes of the future.

A Member of the IET, Phil currently represents Eaton on the BEAMA Smart Housing Association. He has also held a number of other roles within BEAMA over the last 20 years, both within product divisions and technical committees in the UK and in North America.