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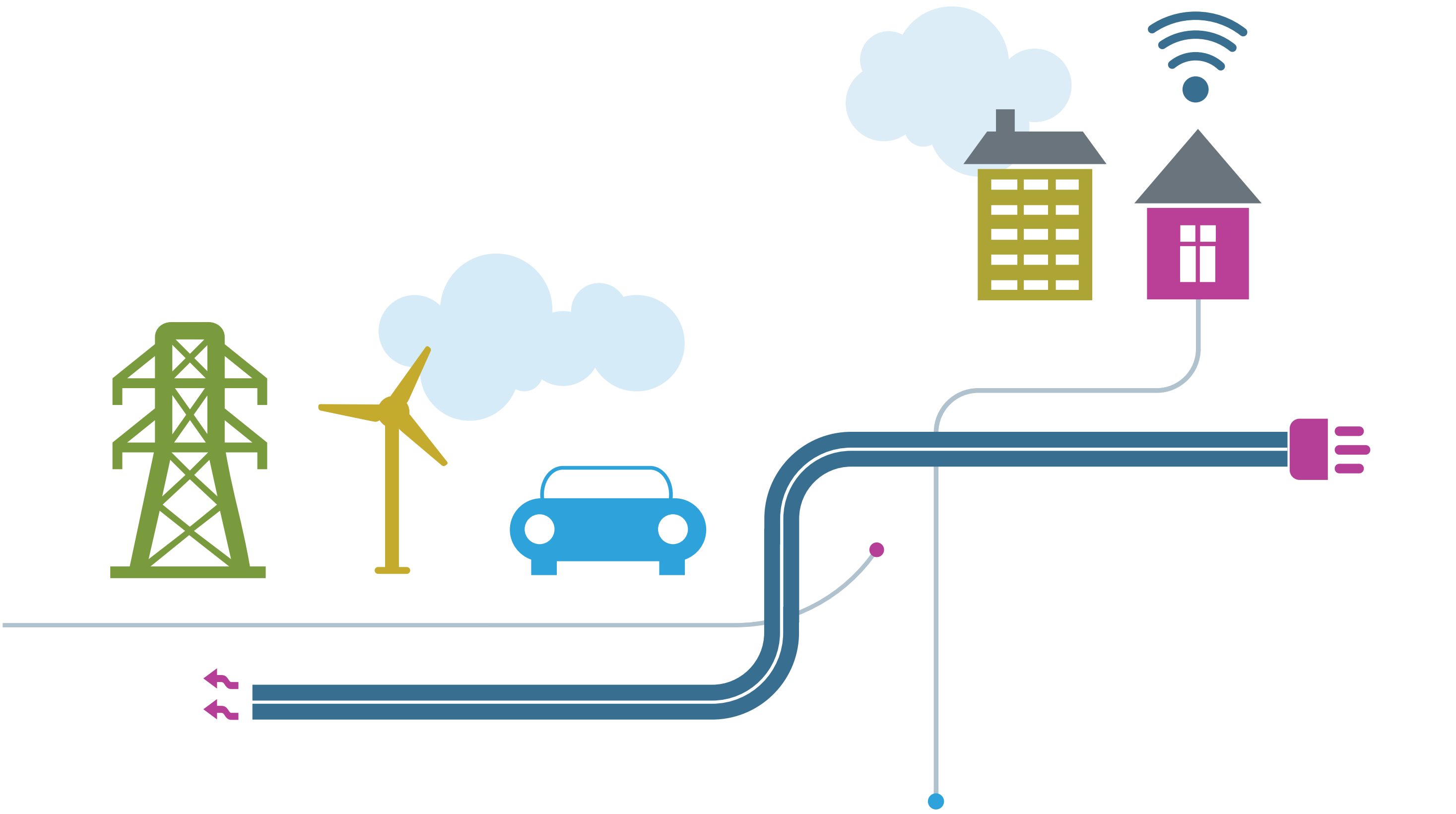
GUIDE TO LOW-VOLTAGE SWITCH AND FUSEGEAR DEVICES



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ABOUT BEAMA

BEAMA is the long established and respected trade association for the electrotechnical sector. The association has a strong track record in the development and implementation of standards to promote safety and product performance for the benefit of manufacturers and their customers.

This Guide provides specifiers, installers and end users, guidance on the low-voltage switch and fusegear devices.

Fuse-links and fusegear supplied by BEAMA members are manufactured under quality systems which are independently assessed to BS EN ISO 9001: Quality Management Systems – Requirements. Member organisations are certified to ISO 14001 Environmental Management Systems – Requirements.

This Guide has been produced by BEAMA's Building Electrical Systems Sector operating under the guidance and authority of BEAMA, supported by specialist central services for guidance on UK Internal Market, European Single Market, Quality Assurance, Legal and Health & Safety matters. BEAMA's Building Electrical Systems Sector comprises of major UK manufacturing companies.

Details of other BEAMA Guides can be found on the BEAMA website
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INTRODUCTION

Edition 4 of IEC 60947-3 includes new content reflecting the changing application for low-voltage switchgear and fusegear devices. The new content includes:

a) **Critical load current tests for DC switches.**

b) **Requirements for a conditional short-circuit rating for disconnectors, switches, and switch-disconnectors protected by circuit-breakers.**

c) **Requirements for connection to aluminium conductors.**

d) **Device power losses measurement**.

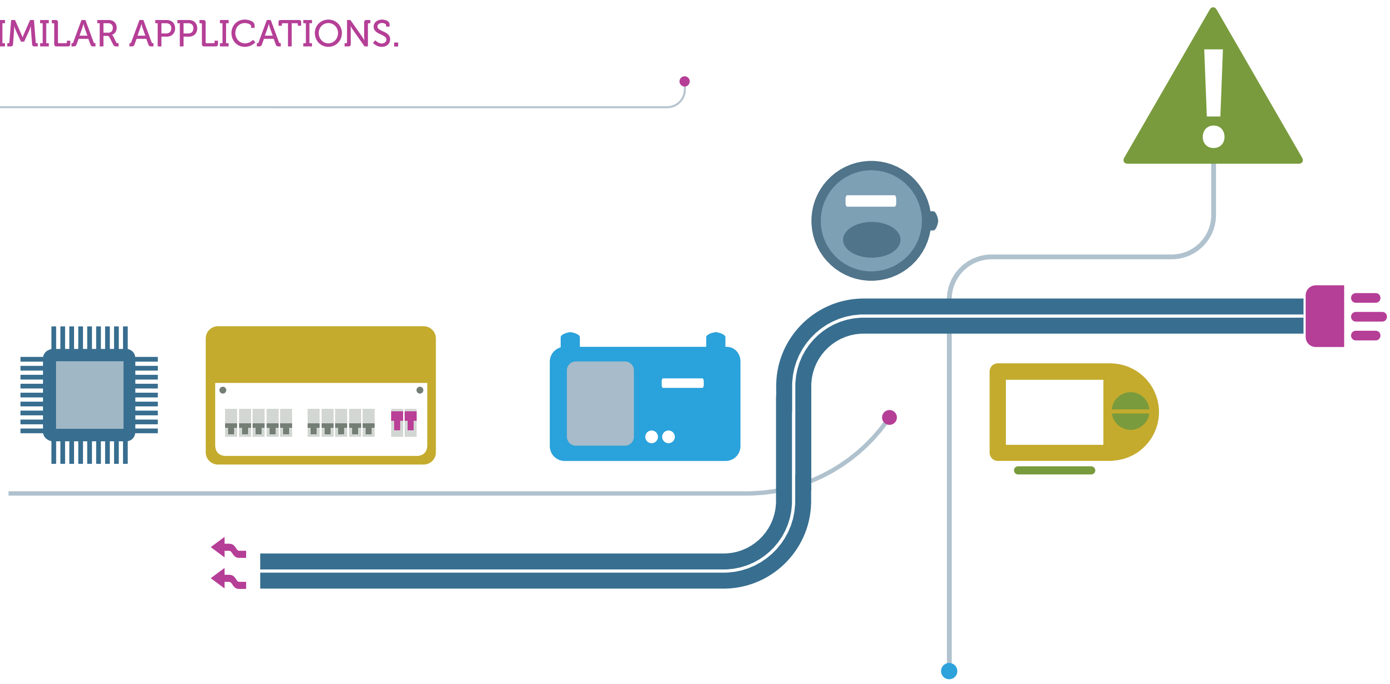
The selection, specification or recommendation of equipment for a particular application can be critical and carries a great deal of responsibility. It is reassuring to know that modern fuse and switchgear is the result of extensive research and cumulative knowledge gained over more than a century.

Fuse developments have been incremental, with the emphasis on increased performance, increased safety and the use of modern materials. Computer modelling of the fuse-link behaviour is now helping designers to develop more compact and modular devices. New technology is ensuring that fuse-links are evolving to meet today's increasing technological demands such as full-range high-speed fuse-links for the protection of semiconductors and fuse-links for the protection of Photo Voltaic (PV) modules and arrays.

This guide considers switching devices according to BS EN 60947-3. Other standards may apply for switches for household and similar applications.

This guide starts from the fuse and continues through to various types of switchgear and fusegear. It is intended as an introduction to fuse and switchgear solutions available from BEAMA members.

THIS GUIDE CONSIDERS SWITCHING DEVICES ACCORDING TO BS EN 60947-3. OTHER STANDARDS MAY APPLY FOR SWITCHES FOR HOUSEHOLD AND SIMILAR APPLICATIONS.



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FUSES

Fuses are an important component in almost every electrical installation, protecting both equipment and personnel. Many fuse-links carry the ASTA 20 endorsement confirming third party assessment of on-going quality and conformity with the original ASTA certified design.

Other approval marks such as VDE and KEMA KEUR may also be carried. In meeting these stringent requirements UK manufacturers offer the customer the highest levels of quality and integrity.

Fuse-links may seem simple devices but their design and construction is complex. The electro-mechanical and thermal properties of the element, body materials and components, together with sand compaction, are all critical factors to fuse performance.

FIGURE 1A: FUSES – BS 88-2 FUSE SYSTEM E (BOLTED)

FIGURE 1B: FUSES – BS 88-2 FUSE SYSTEM G (CLIP IN)

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FUSES

2.1 Fuse definitions

Fuse – A device that by fusing of one or more of its components opens the electrical circuit into which it is inserted by breaking the current when this current exceeds a given value for sufficient time. A fuse comprises all the parts that form the complete device.

Fuse-link – The part of a fuse including the fuse-element(s), intended to be replaced after the fuse has operated.

HRC or HBC fuse-link – High Rupturing Capacity or High Breaking Capacity denotes the ability of a fuse-link to interrupt high fault currents of 6 kA or greater. In UK practice, breaking capacities are generally at least 80 kA AC and 40 kA DC.

Current-limiting fuse-link – A fuse-link that during and by its operation in a specified current range, limits the current to a substantially lower value than the peak value of the prospective current.

"g" fuse-link – (full-range breaking-capacity fuse-link, formerly general purpose fuse-link).

A current-limiting fuse-link capable of breaking under specified conditions all currents, which will cause melting of the fuse-element up to its rated breaking capacity.

"a" fuse-link – (partial-range breaking-capacity fuse-link, formerly back-up fuse-link).

A current-limiting fuse-link capable of breaking under specified conditions all currents between the lowest current indicated on its operating time-current characteristic and its rated breaking capacity.

Fuse-carrier – The moveable part of a fuse, designed to carry the fuse-link.

Fuse-base – The fixed part of a fuse, including terminals, contacts and covers.

Fuse-holder – The combination of the fuse-carrier with its fuse-base.

Fusebank – A configuration of fuse-holders mounted onto a rear fixing rail and having their incoming terminals connected by a common busbar.

Fuseboard – A fusebank or fusebanks mounted in an enclosure together with ancillary equipment (earth/neutral bars) protecting a number of individual circuits.

Fuse-combination unit (FCU) – is a combination of a mechanical switching device and one or more fuses in a composite unit, assembled by the manufacturer or in accordance with his instructions. The term can embrace switch-fuses, switch-disconnector-fuses, fuse-switches and fuse-switch-disconnectors. (See section 3.1).

FIGURE 1C: FUSES – BS 88-3

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FUSES

2.2 Fuse-link ratings

Rated voltage U_n – the maximum nominal voltage that the fuse-link is designed to interrupt. The fuse-link may have an AC rating, a DC rating or both.

Rated current I_n – the maximum value of current that the fuse-link will carry continuously without deterioration under specified conditions.

Current carrying capacity I_z – current-carrying capacity of a cable for continuous service under the particular installation conditions concerned.

Dual rating – commonly used in the UK to designate the current rating of a motor fuse (for example 32M63 means the fuse has a maximum continuous rating of 32 A but the time/current and energy let-through characteristics of a 63 A rating).

Rated breaking capacity – is the value of prospective current that a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour. The fuse link may have an AC breaking capacity, a DC breaking capacity or both and this is the maximum fault current that the fuse-link is certified to break.

Conventional non-fusing current *Inf* – is the value of current specified which the fuse-link is capable of carrying for a specified time (conventional time) without melting.

Conventional fusing current *If* – is the value of current specified (usually 1.6 x In) which causes operation of the fuse-link within a specified time (conventional time). This was previously known as the 'minimum fusing current'.

Conventional time – the time specified for which the fuse-link shall

a) Carry the conventional non-fusing current without operating and

b) Operate within when carrying the conventional fusing current.

Conventional times for gG, gM, gU, gR and gS fuse-links are:

- 1 hour for ratings of 63 A and below
- 2 hours for ratings above 63 A and up to 160 A
- 3 hours for ratings above 160 A and up to 400 A
- 4 hours for ratings above 400 A

Minimum breaking current – The minimum value of current that the fuse-link can satisfactorily interrupt at rated voltage.

Pre-arcing time (melting time) – the interval of time between the beginning of a current large enough to cause a break in the fuse element and the instant when an arc is initiated.

Arcing time (of a fuse-link) – the interval of time between the instant of the initiation of the arc in a fuse and the instant of final arc extinction in that fuse.

Operating time (total clearing time) – sum of the pre-arcing time and the arcing time.

Power dissipation (of a fuse-link) – The power released in a fuse-link carrying a stated value of electric current (usually rated current) under prescribed conditions of use and behaviour.

Fusing factor – A term used previously to indicate the speed of operation of the fuse-link, being the ratio between minimum fusing current and rated current. There were four classes which are similar to the utilization classes of today:

- Class P Fusing factor = Exceeds 1.0 but not exceeding 1.25
- Class Q1 Fusing factor = Exceeds 1.25 but not exceeding 1.5 is the most common and is still referred to in some customer specifications. Now replaced by utilization category gG which includes a cable overload test at $1.45I_Z$
- Class Q2 Fusing factor = exceeds 1.5 but not exceeding 1.75
- Class R Fusing factor = 1.75 and above which was generally referred to as a motor starting fuse-link. Now replaced by utilization category gM

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FUSES

2.3 Fuse-link characteristics

Time-current characteristic – is a curve showing the pre-arcing (melting), or operating, time as a function of current. The time-current curve has a basic tolerance of ± 10% in terms of current.

Cut-off characteristic (peak current) – is a curve showing the cut-off current as a function of prospective current. Cut-off current is the maximum instantaneous value of current let-through by the fuse-link during one half cycle of operation under the most onerous conditions of power factor and asymmetry. Note that the prospective current is expressed in kA r.m.s, whereas the cut-off current is peak kA, so current limitation does occur even when the cut-off current appears to exceed the prospective current.

I^2t characteristic – is a curve or chart showing values of 'pre-arcing' and 'operating' let-through energy as a function of prospective current and voltage, I^2t is proportional to energy and is measured in amperes-squared-seconds (A^2s).

Typically, for gG fuse-links their highest energy let-through is at lower fault currents relative to its current rating. BS 7671 Appendix 3 fuse time / current characteristics stop at 0.1 s. For disconnection times less than 0.1 s, the time / current characteristic is no longer relevant for energy-limiting fuse-link I^2t and the fuse manufacturers I^2t data should be used.

Energy-limiting fuse-link manufacturers typically state a single I^2t value at its maximum breaking capacity, as the I^2t characteristic curve is fundamentally flat for currents causing disconnection times less than 0.1 s up to its maximum breaking capacity. This means that, for calculations requiring an I^2t value for any current resulting in a disconnection time less than 0.1 s, the single I^2t value at its maximum breaking capacity can be used.

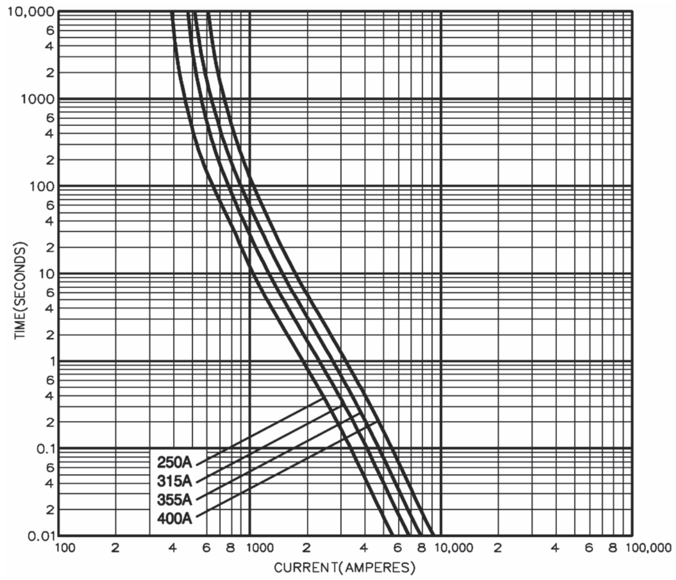

FIGURE 2A: 250-400 A BS 88-2 FUSE TYPICAL TIME/CURRENT CHARACTERISTICS

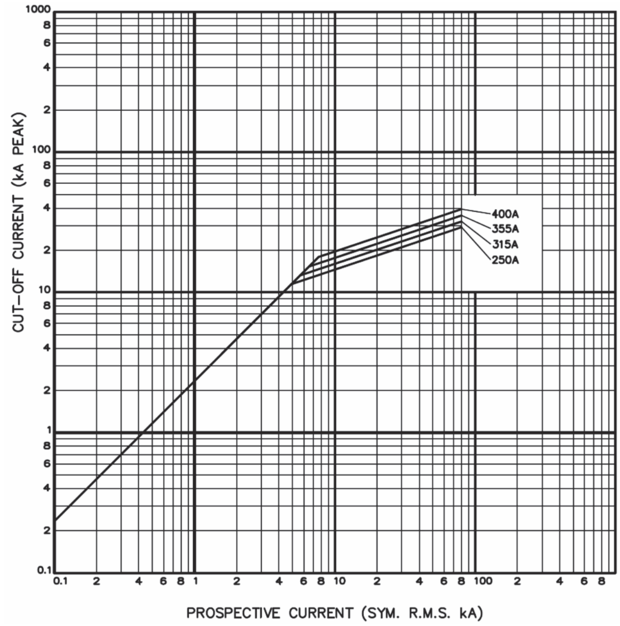

FIGURE 2B: 250-400 A BS 88-2 FUSE TYPICAL CORRESPONDING CUT-OFF CURVES

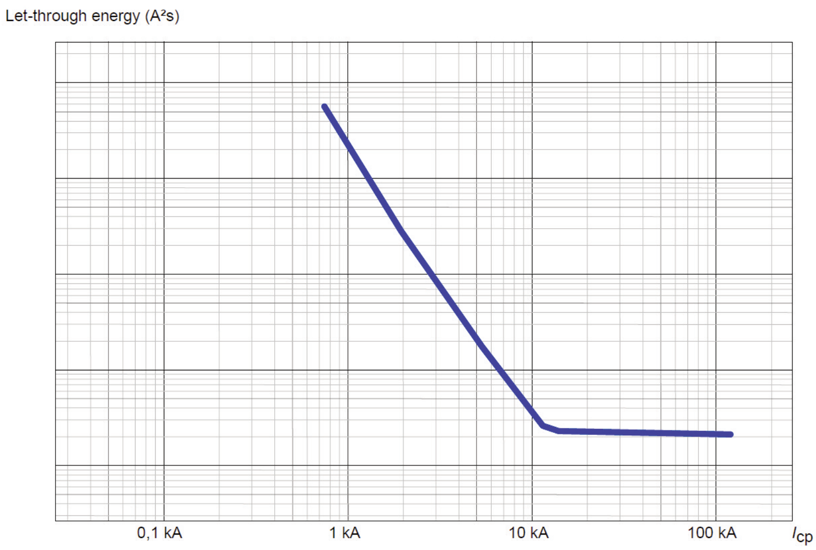

FIGURE 2C: EXAMPLE OF THE I^2t CHARACTERISTIC OF A FUSE

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FUSES

2.4 Breaking range and utilization category

The first letter indicates the breaking range:

"g" fuse-links (full-range breaking capacity fuse-link, typically used for overload and short circuit protection);

"a" fuse-links (partial-range breaking capacity fuse-link, typically used for short circuit protection only).

The second letter indicates the utilization category; this letter defines with accuracy the time-current characteristics, conventional times and currents and gates.

2.5 BS 1362 plug top fuse-links

The UK uses 3-pin fused plugs which must be fitted with a BS 1362 fuse-link. For domestic installations the use of the BS 1363 plug and socket system and the fitting of a BS 1362 fuse-link into a plug is a legal requirement under the UK Plugs and Sockets etc. (Safety) Regulations 1994 (S.I. 1994/1768).

With a correctly fused BS 1363 plug, the flexible cable connected to the equipment is always fully protected against the effects of short circuits or overloads as follows: -

- 3 A fuse protects 0.5 mm^2 or larger cables.
- 7 A fuse protects 0.75 mm^2 or larger cables.
- 13 A fuse protects 1.25 mm^2 or larger cables.

Protection against excessive damage by a short circuit is still achieved even if the smaller cable sizes are inadvertently protected by a 13 A fuse.

The use of BS 1362 fuses to protect flexible cables from overload conditions and from fault conditions such as short-circuits, earth faults and over-currents has long been an essential feature in the UK. It is the only system to offer total protection of flexible cables in this way.

Type	Application (characteristic)	Breaking range
gG	General purpose	Full range
gM	Motor circuit protection	Full range
aM	Motor circuit protection	Partial range (short circuit only)
aR	Semiconductor protection	Partial range (short circuit only)
gR	Semiconductor and conductor protection	Full range (optimised to low I2t values)
gS	Semiconductor and conductor protection	Full range (optimised to low power dissipation)
gU	Electricity supply networks	Full range
gPV	PV module and array protection	Full range
gTr	Transformer protection	Full range
gL, gF, gI, gII	Former types of general purpose fuses replaced by type gG	Full range

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SWITCHING DEVICES

3.1 Definitions

Switching is the ability to make and break defined load and overload currents at a rated operational voltage, for the design life of the device. Switching devices come within the scope of BS EN 60947-3: Specification for low-voltage switchgear and controlgear. Switches, disconnectors, switch-disconnectors and fuse-combination units, which details the following definitions.

Switch – mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions which may include specified operating overload conditions and also carrying, for a specified time, currents under specified abnormal circuit conditions such as those of short-circuit.

NOTE: A switch may be capable of making, but not breaking, short-circuit currents.

Disconnector – mechanical switching device which, in the open position, complies with the requirements specified for the isolating function.

NOTE: A disconnector is capable of opening and closing a circuit when either a negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying, for a specified time, currents under abnormal conditions such as those of short-circuit.

Fuse-combination unit – combination of a mechanical switching device and one or more fuses in a composite unit, assembled by the manufacturer or in accordance with their instructions.

Switch-fuse – switch in which one or more poles have a fuse in series in a composite unit.

Switch-fuse single opening – switch-fuse which provides an interruption in the circuit on one side of the fuse-link only.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Switch-fuse double opening – switch-fuse which provides an interruption in the circuit on both sides of the fuse-link.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Fuse-switch – switch in which a fuse-link or fuse-carrier with fuse-link forms the moving contact.

Fuse-switch single opening – fuse-switch which provides an interruption in the circuit on one side of the fuse-link only.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Fuse-switch double opening – fuse-switch which provides an interruption in the circuit on both sides of the fuse-link.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Disconnector-fuse – disconnector in which one or more poles have a fuse in series in a composite unit.

Disconnector-fuse single opening – disconnector-fuse which provides an opening in the circuit on at least one side of the fuse-link, that satisfies the requirements specified for the isolating function.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Disconnector-fuse double opening – disconnector-fuse which provides an opening in the circuit, that satisfies the requirements specified for the isolating function, on both sides of the fuse-link.

Fuse-disconnector – disconnector in which a fuse-link or fuse-carrier with fuse-link forms the moving contact.

Fuse-disconnector single opening – fuse-disconnector which provides an opening in the circuit on at least one side of the fuse-link that satisfies the requirements specified for the isolating function.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Fuse-disconnector double opening – fuse-disconnector which provides an opening in the circuit, that satisfies the requirements specified for the isolating function, on both sides of the fuse-link.

Switch-disconnector-fuse – switch-disconnector in which one or more poles have a fuse in series in a composite unit.

Switch-disconnector-fuse single opening – switch-disconnector-fuse which provides an interruption in the circuit on at least one side of the fuse-link that satisfies the requirements specified for the isolating function.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

Switch-disconnector-fuse double opening – switch-disconnector-fuse which provides an interruption in the circuit on both sides of the fuse-link that satisfies the requirements specified for the isolating function.

Fuse-switch-disconnector – switch-disconnector in which a fuse-link or fuse-carrier with fuse-link forms the moving contact.

Fuse-switch-disconnector single opening – fuse-switch-disconnector which provides an interruption in the circuit on at least one side of the fuse-link that satisfies the requirements specified for the isolating function.

NOTE: With this arrangement safety precautions may be necessary when removing fuse-links.

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SWITCHING DEVICES

Fuse-switch-disconnector double opening – fuse-switch-disconnector which provides an interruption in the circuit on both sides of the fuse-link that satisfies the requirements specified for the isolating function

Single pole operated three pole switch – mechanical unit consisting of three individually operable single pole switches and/or disconnecting units according to this part, rated as a complete unit for use in a three-phase system

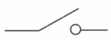
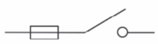
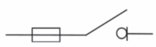
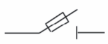
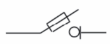
NOTE: These mechanical units are intended for power distribution systems where switching and/or isolation of an individual phase may be necessary and they should not be used for the switching of the primary circuit of three-phase equipment.

Whilst at first sight these definitions may appear complex and confusing there is logic to the terminology with each device having its own specific features and functions. The key to identifying the functions of a device and specifying it for a particular application rests in the recognition of terms and the order in which these terms are used in the definition.

The position of the word 'fuse' at the beginning of the description indicates that the fuse-link forms part of the moving contact system whereas the word 'fuse' at the end indicates a static fuse-link.

The symbols used to identify these functions are shown in the following table from BS EN 60947-3 and must be placed on the front of the device in such a position that they are visible when the device is installed.

TABLE 1: SUMMARY OF EQUIPMENT DEFINITIONS

Functions		
Making and breaking current	Isolating	Making, breaking and isolating
Switch 	Disconnector 	Switch-disconnector 
Fuse-combination units		
Switch-fuse single opening[a] 	Disconnector-fuse single opening[a] 	Switch-disconnector-fuse single opening[a] 
Switch-fuse double opening[b] 	Disconnector-fuse double opening 	Switch-disconnector-fuse double opening[b] 
Fuse-switch single opening[a] 	Fuse-disconnector single opening[a] 	Fuse-switch-disconnector single opening[a] 
Fuse-switch double opening[b] 	Fuse-disconnector double opening 	Fuse-switch-disconnector double opening[b] 
NOTE Equipment shown as single opening may comprise multiple openings in series		

a   The fuse may be on either side of the contacts of the equipment.
b   Depending on the design, breaking may take place on one or both sides of the fuse-link

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SWITCHING DEVICES

3.2 Application of switching devices

All switching and disconnecting devices should be selected to suit the needs of the application taking into account:

- the full load current of the circuit
- making and breaking requirements
- frequent or infrequent operations and
- short circuit performance.

In accordance with BS EN 60947-3 all switches and disconnectors have a rated short time current withstand capability of a minimum of twelve times the rated current for one second. Switches without fuse protection are also generally capable of making onto the same prospective short circuit current. However, a manufacturer may offer higher short circuit rating including conditional short circuit making and withstand capabilities.

Fused switching devices have a conditional short circuit rating based on the integral fuse link limiting the prospective short circuit current. The manufacturer will declare the maximum prospective short circuit current permissible at the incoming terminals of the device, for a given fuse link within the device.

The characteristic of the loads to be switched and the frequency of switching differ between applications. Within BS EN 60947-3 these differing needs have been divided into ‘utilization categories’; which take into account frequency and number of operations, overload switching needs, power factor or time constant of the circuit.

3.3 Category of Duty

Switching devices are classified according to Utilization Category, or Category of Duty, thus: -

The Utilization Category should be suffixed ‘A’ or ‘B’ to indicate suitability for either frequent or infrequent use in service respectively. See 3.4 for further details.

Utilization Category	Typical Applications
AC20/DC20	**Connecting and disconnecting under no-load** Assumes all switching operations are carried out by other capable devices before this device is operated. AC20/DC20 disconnectors should not be used to break load current.
AC21/DC21	**Switching of resistive loads including moderate overloads.** Suitable for purely resistive type loads. Device can switch 150% of its rated current under overload conditions. *Example: – an AC21A switch may be used to control a heater (excluding tungsten element type) that is switched on and off daily.*
AC22/DC22	**Switching of mixed resistive / inductive loads, including moderate overloads.** Suitable for mixed resistive / inductive loads. Device can switch 300% for AC22 or 400% for DC22 of its rated current under overload conditions. *Example: – an AC22B switch may be used for maintenance purposes as the incoming circuit to a switch/panel board or distribution board.*
AC23/DC23	**Switching of highly inductive loads.** Provided mainly as back-up to other means of switching, e.g. Contactors. In the event of failure of the functional device, an AC23/DC23 type device can safely interrupt a stalled motor current. Where devices are the only means of controlling individual motors, they should comply with the requirements of Appendix A of BS EN 60947-3. Example 1): an AC23B fuse switch may be used to disconnect a motor under stalled conditions. Example 2): an AC23B switch-disconnector, with or without fuses may be used as the supply disconnecting device for each incoming source of supply to a machine(s). This is one option in BS EN 60204-1 Safety of machinery.
AC12e	**Switching of motor loads with higher locked rotor currents** Provided for asynchronous motors of design NE and HE according to BS EN 60034-12, having extended/increased locked rotor apparent power and current than degree N and H respectively, to achieve a higher efficiency class according to the requirements of BS EN 60034-30-1.
	Switching of PV circuits.
DC-PV0	Opening and closing a PV circuit to provide disconnection when no current is flowing.
DC-PV1	Connecting and disconnecting single PV string(s) where reverse currents and significant overcurrent cannot occur.
DC-PV2	Connecting and disconnecting PV circuits where significant overcurrents may prevail and where current flow can be in both directions; for example, where several strings are connected in parallel and to the same inverter, or, one or more strings with a battery.

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SWITCHING DEVICES

Switch Disconnectors for AC21/DC21, AC22/DC22 and AC23/DC23 also have to meet the requirements of AC20/DC20.

For specific and special applications such as switching of capacitors and tungsten lamps, the manufacturers' advice should be sought.

3.4 Frequent and infrequent use

The Utilization Category should be suffixed 'A' or 'B' to indicate suitability for either frequent or infrequent use in service respectively, e.g. an AC21A device can be used to switch resistive type loads on frequent operations and an AC23B device, although suitable for high inductive loads, can only be used infrequently.

The standard does not give a definition of what is meant by frequent or infrequent use, but a reasonable definition for switching full load current would be as follows:

- Frequent (A) – Up to 5 times a day for devices rated say up to 100 A; once a week for higher rated devices.
- Infrequent (B) – Once a week for devices rated up to say 100 A; once a month for the higher rated devices.

4
FUSE ASSEMBLIES

4.1 Fuse-holders

Fuse-holders for the UK market are designed to meet the requirements of BS HD 60269-2/BS 88-2. The fuse-holders normally consist of a separate base and a carrier with the base containing the main incoming and outgoing cable terminals and the carrier holding the fuse-link. Cable terminals are shrouded and the base and carrier mouldings prevent finger contact with live parts as the fuse-link is withdrawn.

Fuse-holders are a common means of utilising fuse-links in industrial environments. Two main types are utilised: -

- BS HD 60269-2/BS 88-2 fuse system E for use with bolted tag type fuse-links up to 400 A
- BS HD 60269-2/BS 88-2 fuse system G for use with offset blade tag fuse-links up to 63 A

FIGURE 3A: FUSE-HOLDERS – BS88-2 FUSE SYSTEM E (BOLTED)

FIGURE 3B: FUSE-HOLDERS – BS 88-2 FUSE SYSTEM G (CLIP IN)

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FUSE ASSEMBLIES

4.1.1 Protection against electric shock

For safety reasons, base terminal blocks are shrouded and carrier contacts protected by the sides of the base moulding so that accidental contact with live parts is prevented when the fuse-carrier is withdrawn or replaced.

BS EN 60269-1/BS 88-1 identifies three states of the fuse to be taken into account when considering protection of personnel against electric shock.

(i) When the complete fuse is properly mounted, installed and wired with fuse-base, fuse-link, fuse-carrier and enclosure forming part of the fuse (normal service condition);

(ii) During the replacement of the fuse-link;

(iii) When the fuse-link, and where applicable, the fuse-carrier is removed

Both types of fuse-holder defined in 4.1 above provide a degree of protection IP2X in all of the three states, thereby providing compliance with BS EN 60269-1/BS 88- 1 and BS HD 60269-2/BS 88-2

4.1.2 Cable Connection

Various types of cable connection are available, the most common ones being:

Front/Front – cable entry at top and bottom of the fuse-base.

Back Stud – two threaded back studs for cable connection.

Front/Back Stud – combination of the above types.

Front/Busbar – top or bottom cable entry at one end and a special terminal block for connection to a busbar at the opposite end.

Fuse-holder/fuse-link combinations are widely used within industry for circuit protection and can be used either as stand-alone single or three-phase devices or incorporated into distribution boards or control panels.

4.2 Fusebanks

Fuse-holders mounted onto a rear fixing rail or strap and having their incoming terminals connected together by a common busbar are termed fusebanks and are typically available in 2, 3, 4, 6, 8, 10 or 12-way configurations. Each bank may include the customer's main incoming terminal and the assembly is fully shrouded against accidental contact. Complementary neutral bar and earth bar arrangements and side rails are available to complete the package and allow assembly into distribution systems, control panels or custom-built fuse-boards.

FIGURE 4: FUSEBANKS

4.3 Distribution fuseboards

Distribution fuseboards are manufactured as a complete assembly of fusebanks, incoming main terminals, neutral and earth bars and side rails within an enclosure. Single Phase and Neutral (SP&N), Double Pole (DP) and Three Phase and Neutral (TP&N) types are available with typical ratings of 20, 32, 63, 100 and 200 A and with between 2 to 12 ways. They conform to BS EN 61439-2 or BS EN 61439-3 depending on the application.

They provide an effective means of supplying centralised distribution systems giving protection throughout industrial and commercial premises.
Their use enables systems to be sub-divided so that if a fault occurs in one part of the system, downstream from the main fuse-link, other healthy circuits or sub-systems remain unaffected.

In general, all distribution fuseboards should have a means of isolation, either as an integral component or as a separate unit. The most common method is to supply the distribution fuseboard through a switch-disconnector.

4.4 IP (International Protection) codes

Selection of enclosures is determined by external influences (application, location, environment, etc.) and is specified in accordance with BS EN 60529 Specification for degrees of protection provided by enclosures (IP code).

The specified IP Code only applies when the equipment/enclosure is properly installed, according to the manufacturer's instructions. Further detailed information on the definitions and application of IP Codes is included in the BEAMA Guide to IP Codes.

5
GENERAL APPLICATION OF FUSE-LINKS

The application of HRC fuse-links for circuit protection is relatively straightforward. However, a few general rules must be observed.

5.1 Circuit voltage

Fuse-links are voltage-sensitive devices and it is important to note that satisfactory operation of a fuse-link under fault conditions is dependent upon the applied voltage. They must not therefore be used in circuits above their voltage capability. They can, however, be used satisfactorily in circuits at lower voltages.

5.2 Full load current

The continuous current rating of the fuse-link should not be less than the full load current of the circuit, although temporary overloads such as motor starting surges may exceed this value in accordance with the time current-characteristic.

5.3 Fault level

Fuse-links are generally assigned standardised breaking capacities which are normally in excess of any fault current likely to be encountered in service. BS fuse-links for industrial applications are generally tested for a breaking capacity of 80 kA AC and 40 kA DC.

NOTE: A fuse lets most energy through at low fault currents (relative to its current rating) and as a consequence the highest conductor temperature will occur at the minimum fault current because the disconnection time is longest.

5.4 Air temperature

Fuse-links are thermal devices which will carry full rated current in surrounding air temperatures of up to 35 °C. If they are to be operated at elevated air temperatures resulting from mutual heating effect or air temperatures within the enclosure rising above 35 °C it may be necessary to reduce the assigned current rating.

The de-rating factor should be as advised by the manufacturer after taking into account all the relevant details of the application. In the absence of the manufacturer's information, a derating of 0.5% of rated current per degree centigrade above 35 °C may be used.

The effects on the performance of fuse-links operating at elevated temperatures are: -

5.4.1 Temperature rise

An increase in air temperature will result in a proportional increase in the temperature rise of the fuse-link.

5.4.2 Time/current characteristics

For relatively long operating times there will be a decrease, usually small, in the operating time of fuse-links at elevated air temperatures. This is a useful attribute as the current carrying ability of cable will also similarly be reduced at higher air temperatures. At high levels of fault current, where fuse-links are operating under adiabatic conditions, the characteristics will be unaffected by high air temperatures.

5.5 Selectivity

Selectivity of protective devices is an important point to be considered when designing low-voltage installations. The aim of selectivity is to limit the effects of a fault to the circuit concerned. Only the faulty circuit should be disconnected while the others should remain in service. Selectivity is achieved if a fault is cleared by the protective device situated immediately upstream of the fault without operation of other protective devices.

For the purposes of this publication, consideration will be restricted to two of the main applications.

5.5.1 Selectivity between fuse-links

It is standard practice to find HRC fuse-links, particularly low-voltage types, in series with one another to provide protection at different levels in an electrical installation. Selectivity between fuse-links can be checked by ensuring that the time/current characteristics do not overlap at any point. Due allowance should be made for the $\pm$ 10% tolerance with respect to current. For fault levels which give fuse-link operating times of 0.1 seconds or less it is necessary to ensure that the total let through energy (I^2t) of the minor fuse-link (the one nearest the fault) does not exceed the pre-arcing energy (I^2t) of the major fuse link (the next one upstream) at the applied system voltage.

Fuse-links according to BS EN 60269-2/BS 88-2 of the same type, e.g. gG, with rated currents $\geq$ 16 A, meet these total selectivity requirements (both overload and short circuit) by definition if the ratio of rated currents is 1.6:1 or higher. No additional verification by the user is therefore needed.

In practice, the total I^2t values of HRC fuse-links are usually significantly less than the worst case (phase to phase fault at 0.1 to 0.2 fault current power factor) published by manufacturers. Consequently, the fuses will discriminate with each other at fault levels up to 80 kA at 400 V. In most cases a discrimination ratio of 1.6:1 or less can be achieved even though the published data on I^2t values may indicate otherwise. This lower discrimination ratio can provide significant economic benefits in modern installations.

5
GENERAL APPLICATION OF FUSE-LINKS

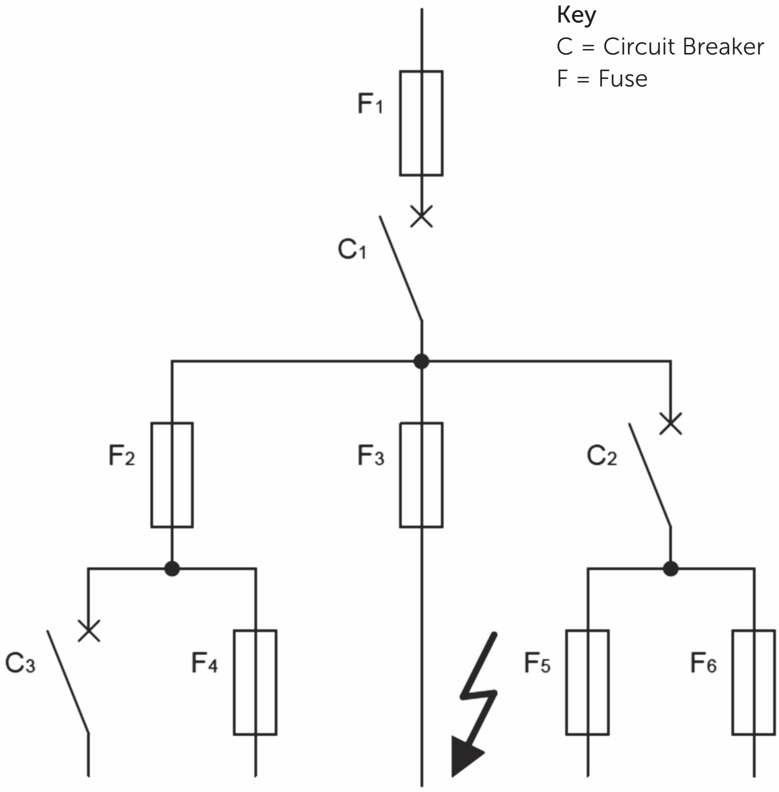

FIGURE 5: SELECTIVITY BETWEEN FUSE-LINKS IN A TYPICAL THREE-PHASE DISTRIBUTION SYSTEM (ONLY ONE PHASE SHOWN)

With properly selected HRC fuse-links, minor fuse-link F3 operates on a fault and major fuse-link F1 remains unaffected.

5.5.2 Selectivity between fuse-links and other protective devices

Protective devices other than fuse-links, for example circuit-breakers, are generally electromechanical devices having definite minimum operating times. These operating times tend to be longer than those of similar rated fuse-links except at low values of overcurrent.

5.5.2.1 Selectivity of circuit-breakers upstream of fuse-links

Selectivity in the overload zone is determined by the comparison of time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of the fuses in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

For fault currents, selectivity is assured up to the fault current level at which the peak let-through current of the fuse is less than the peak value corresponding to the instantaneous tripping level (I_i) of the circuit-breaker taking into account tolerances.

5.5.2.2 Selectivity of fuse-links upstream of circuit-breakers

Selectivity will be achieved if the maximum tripping time-current characteristic of the circuit-breaker does not intersect with the time-current characteristics of the fuse-link and the maximum operating I^2t value of the circuit-breaker is less than the minimum pre-arcing I^2t of the fuse-link.

6
APPLICATION OF FUSE-LINKS TO SPECIFIC EQUIPMENT

6.1 Conductor and cable protection

6.1.1 Protection against both overload and fault current

Chapter 43 of BS 7671, IET Requirements for Electrical Installations (Wiring Regulations), requires live conductors to be protected against overcurrent. Type gG fuse-links with a current rating equal to or less than the cable rating provide complete protection against both overload and fault currents as required by regulation 432.1.

6.1.2 Protection of conductors against fault current only

In some circuits (e.g. motor circuits) it is not economical or practical to match fuse-links and cable ratings to provide complete cable protection in the manner described previously, because the motors produce significant over-currents during starting. In such cases the fuse-links are chosen to withstand the temporary over-current conditions and provide only short-circuit protection to the associated cables and other circuit components. Overload protection is provided by other means such as overload releases. This is in accordance with BS 7671 regulation 432.3.

6.1.3 Back-up protection

When connected in series with other protective devices, for example circuit breakers, the current/energy limiting capability of fuses can enable the breaking capacity of the down-stream device to be less than the prospective short-circuit current of the circuit. Such an arrangement is recognised by BS 7671 regulation 434.5.1.

6.2 Motor Circuit Protection

6.2.1 AC Motors

Fuse-links are commonly used as part of the protection for motors and motor-starter circuits.

General-purpose type gG fuse-links can be used for this purpose. Their current rating is chosen to withstand the starting current and duty of the motor and maybe higher than the nominal rated current of the motor. This is dependent on the method of starting used, for example:

- Direct on-line (DOL) starting – 8.5 times full load current for a run up time of 10 seconds,
- Star delta or autotransformer (assisted) starting – 3.5 times full load current for a run up time of 20 seconds.

Even higher rated fuse links may be necessary if any of the following conditions occur singly or in combination:

- Starting currents in excess of those assumed above,
- Long run-up times due to high inertia loads.
- Larger number of starts per operating cycle (standard recommendations usually allow for two starts in rapid succession and up to eight starts per hour).

Type gM fuse-links have a dual rating which is characterised by two current values. The first is the assigned maximum continuous current of the fuse-link and associated fuse-holder. The second indicates the equivalent time-current characteristic to which the fuse-link conforms and therefore its motor starting ability. These two ratings are normally separated by the letter M which defines the application. For example, a 32M63 fuse-link is intended for use in the protection of motor circuits and has a maximum continuous rating of 32 A but the short-circuit characteristics of a 63 A rating. This means that the associated equipment need only be rated at 32 A, thereby providing significant economies in size and cost against 63 A equipment.

Other factors to be considered in the selection of fuse-links for motor circuit protection are cable protection and overload protection. Most manufacturers publish tables showing the maximum fuse-link rating which will give short-circuit protection for a particular cable size. If overload protection of the cable is also required it will be necessary to select a cable size that has a normal current carrying capability greater than, or equal to, the rating of the fuse-link (for dual rated fuse-links the higher of the two ratings is the one to be considered.)
In general overload protection is provided by the motor starter. Correct selection of the fuse-link rating, using the criteria given above, will provide co-ordination between all of the main components of the system.

6.2.2 Fuse-link and motor-starter/contactor coordination

There are benefits in specifying motor starters with type 2 co-ordination to BS EN 60947-4-1: Electromechanical contactors and motor-starters. This can be achieved by using BS HD 60269-2/BS 88-2 fuse-links type gG or gM in combination with correctly selected contactors and overload relays as specified by the motor starter manufacturer.

Type 2 co-ordination requires that under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use.

Type 1 co-ordination offers the same degree of required protection to persons and installations however, the starter may not be suitable for further service after being subject to a short circuit without replacement of parts.

6.2.3 DC Motors

With the majority of DC motors the starting current is controlled to a relatively low level. For standard applications, a fuse-link having a rating close to, but not less than, the motor full load current will be sufficient to withstand the starting conditions as well as providing adequate short-circuit

6 APPLICATION OF FUSE-LINKS TO SPECIFIC EQUIPMENT

protection . It is important to ensure that the DC voltage rating of the fuse-link is sufficient for the application as AC and DC voltage ratings for protective devices normally differ.

6.3 Transformer Protection

6.3.1 Distribution transformers

Low-voltage fuse-links used on the primary side of transformers should be selected to have a sufficiently high current rating to withstand the transformer magnetising inrush current; typically, as follows:

20 times transformer primary full load current for 0.01 of a second

12 times transformer primary full load current for 0.1 of a second

In most cases a fuse-link rating of 1.5 to 2 times the primary current rating of the transformer will fulfil the above requirements.

Also, selectivity between primary and secondary fuse-links and any other over-current protection has to be established taking into account the appropriate transformation ratio.

6.3.2 Control circuit transformers

For these low power transformers, the peak inrush magnetising current in the first half cycle can be many times the full load current. Some control circuit transformers may have internal thermal protection since the over-current devices on the primary side would need to be greatly oversized to account for the very high inrush currents.

6.4 Power factor correction capacitor protection

The use of fuses according to BS HD 60269-2/BS 88-2 type gG for short-circuit protection of power factor correction capacitors has been a well-established engineering practice for many years. Reliable functioning of gG fuses in such applications requires consideration of the following typical circuit behaviour:

- High inrush currents up to 100 times rated current of the capacitor
- Continuous operating current up to 1.5 times rated current of the capacitor (including harmonics)
- Increasing service voltage up to 1.2 times during low-load periods for 5 min;
- Fluctuation of the service voltage up to 1.1 times for 8 hours
- Capacitance (and subsequently operating current) tolerances of +15 %;

The rated current of the fuse-link is selected so that:

- The inrush currents do not melt or deteriorate the fuse-element,
- The potential over-currents do not lead to premature operation of the fuse-links.
- The rated current of the gG fuse-links is selected to be 1.6 to 2 times the rated current of the capacitor unit bank.

Under these conditions, the fuse-links provide reliable short-circuit protection to the capacitors. Overload protection, if necessary, must be provided by additional devices.

6.5 Semiconductor device protection

In order to provide protection for devices such as power electronic diodes and thyristors, it is necessary to select high-speed fuse-links that have a lower energy (I^2t) and peak let-through current than the device's withstand capability. Applications are complex and frequently involve pulsed current, high temperatures and forced air or water cooling. Technical data on device withstand is usually readily available from semiconductor manufacturers. Industrial fuse-links to BS EN 60269-2/BS 88-2 do not normally meet these criteria and high speed fuse-links conforming to BS EN 60269-4/BS 88-4 should be used instead. This standard also contains guidance for the co-ordination of high-speed fuse-links with semiconductor devices in Annex AA.

IEC/TR 60146-6 is an application guide for fuse protection of semiconductor inverters against over-currents. It is limited to line commutated inverters in single-way and double-way connections. This technical report advises the specific fuse features required to be observed to ensure correct application of semiconductor fuses in inverters.

Type aR fuse-links are intended primarily for high-speed short-circuit protection of semiconductor devices and may only be suitable for operating times below 30 seconds and be used at currents greater than a factor given by the fuse-link manufacturer. Subsequently type gR and gS fuse-links have been introduced with full range breaking capacity, high speed operation and the ability to protect both semiconductor devices and cables from sustained overcurrent instead of relying on a further protective device. gR fuse-links are optimised for low I^2t values and gS are optimised for low power dissipation.

PD IEC TR 60269-5 provides further guidance on application of high speed fuse-links.

Other than the above guidelines it is difficult to provide general recommendations for fuse-link selection for these applications and guidance should be obtained from the fuse-link manufacturer or device manufacturer for specific applications.

6.6 Welding equipment protection

A wide variety of electric welding equipment is available covering many different welding techniques. The nature

6 APPLICATION OF FUSE-LINKS TO SPECIFIC EQUIPMENT

of the load which is imposed upon the circuit is equally diverse. In all instances the load is a fluctuating one making it necessary to consider each application on its own merits when selecting the protective device. However, in general, fuse-link selection can be taken as being dependant on the value of r.m.s load current (taking the duty cycle into account). Selection of the next highest rating of fuse-link will normally be sufficient to provide adequate protection.

6.7 Household protection

BS HD 60269-3/BS 88-3 type IIa (63 or 80 A) or type IIb (100 A) house service cut-out fuse-links are used at the incoming supply terminals of houses, apartments and some small commercial units. Consumer units may be fitted with type I fuse-links, colour and size coded to prevent incorrect ratings being fitted.

BS HD 60269-3/BS 88-3 has superseded the well-known former UK national standard, BS 1361 which has been withdrawn as conflicting with HD 60269-3 but the key performance characteristics are the same.

6.8 Fluorescent and LED lighting protection

Fuse-links protecting fluorescent or LED lighting loads must be able to withstand the high inrush currents at switch on which may be as high as 50 or 100 x full load current (FLC) for less than 0.5 ms. A fuse-link rating of 2 x FLC will normally be adequate.

6.9 Heating equipment protection

As transients and surges are not normally associated with conventional* resistive heating equipment it is only necessary to select the HRC fuse-link rating nearest to, but not less than, the normal full load current of the equipment. This will provide adequate overload and short-circuit protection.

**Tungsten, quartz and other forms of heating may require special consideration.*

6.10 Protection of instruments and meters

Portable and switchboard instruments and meters are often used in locations where prospective fault currents are high. In such cases flash-over or failure in the instrument can cause extensive damage to the instrument and nearby equipment and may also present a hazard to personnel. In order to avoid such occurrences, the use of a suitable low-rating HRC fuse-link, in series with the potential (voltage) coil of the instrument, is recommended.

6.11 Photovoltaic system protection

Protection of PV strings poses unusual problems with high voltages (generally up to 600 or 1000 V DC), low load and low fault currents with the exception of capacitor discharge from the inverter or batteries which have a high peak and rate of rise of current. Also, current output varies rapidly depending on the irradiance incident on the modules during the day time and shading by cloud cover. Coupled with extreme temperature variations in desert conditions of -40 °C to +90 °C, this has led to the development of gPV fuse-link ranges specifically for photovoltaic string, sub array and array protection under these onerous conditions. The output from strings of solar modules are often fed into combiner boxes which contain gPV fuse-links in compact modular fuse-holders, monitoring equipment and a switch disconnector to isolate the output from downstream sub-array or array combiner boxes with their own higher-rating gPV fuse-links usually mounted in fuse-bases. String fuse-links are generally rated at 1 to 32 A, sub-array and array fuse-links rated at 32 to 630 A, but development is continually pushing current and voltage ratings higher.

BS EN 60269-6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems, was developed to standardize the performance and dimensions of fuse-links specifically designed to protect these new applications.

Similarly, the DC currents in PV networks have particular characteristics and switching needs. Time constants are specific to the application. In some instances an overload capability is not required, in others an overload/short circuit capability is essential. Accordingly, switching devices have been developed to suit the needs of the application. They should be selected on the basis of their utilisation category (see 3.3) and as required by the needs of the electrical network at the point where they are installed. Specifically, DC switches are required on the output of the combiner boxes since PV strings continue to generate as long as sun light is present.

7 STANDARDS

7.1 Fuse standards

Low-voltage fuse standards have been rationalized by the IEC fuse technical committee (TC32) and adopted by CENELEC for use as National Standards within the EU. The UK has adopted the standards listed below as designated standards. Note that they are dual numbered with the old BS 88 title which has been in existence since 1919.

- BS EN 60269-1/BS 88-1 Low-voltage fuses. General requirements
- BS HD 60269-2/BS 88-2 Low-voltage fuses. Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application). Examples of standardized systems of fuses A to K
- BS HD 60269-3/BS 88-3 Low-voltage fuses. Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar application). Examples of standardized systems of fuses A to F
- BS EN 60269-4/BS 88-4 Low-voltage fuses. Supplementary requirements for fuse-links for the protection of semiconductor devices
- PD IEC/TR 60269-5 Low-voltage fuses. Guidance for the application of low-voltage fuses
- BS EN 60269-6 Low-voltage fuses. Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

Previous versions of UK fuse standards have been withdrawn after their contents were written into the above series including the following:

- BS 88-2.1 and BS 88-2.2 are now both incorporated in BS HD 60269-2/BS 88-2
- BS 88-5 and BS 88-6 are now both incorporated in BS HD 60269-2/BS 88-2
- BS 1361 is incorporated in BS HD 60269-3/BS 88-3

7.2 Switchgear and controlgear standards

BS EN 60947 Series: Specification for low-voltage switchgear and controlgear is divided into the following parts: -

- BS EN 60947-1: General rules
- BS EN 60947-2: Circuit-breakers
- BS EN 60947-3: Switches, disconnectors, switch-disconnectors and fuse-combination units
- BS EN 60947-4 Series: Contactors and motor starters
- BS EN 60947-5 Series: Control-circuit devices and switching elements
- BS EN 60947-6 Series: Multiple function equipment
- BS EN 60947-7 Series: Ancillary equipment
- BS EN 60947-8: Control units for built-in thermal protection (PTC) for rotating electrical machines

7.3 Other relevant standards

The following standards are also mentioned in this guide.

- BS 1362: Specification for general purpose fuse-links for domestic and similar purposes (primarily for use in plugs)
- BS 1363-1: 13 A plugs, socket-outlets, adaptors and connection units. Specification for rewirable and non-rewirable 13 A fused plugs
- BS 7671: Requirements for Electrical Installations (IET Wiring Regulations)
- BS EN 61439 series: Specification for low-voltage switchgear and controlgear assemblies
- BS EN 60529: Specification for degrees of protection provided by enclosures (IP code)
- BS EN 60204-1 Safety of machinery
- BS EN 60034-12 Rotating electrical machines. Starting performance of single-speed three-phase cage induction motors
- BS EN 60034-30-1 Rotating electrical machines. Efficiency classes of line operated AC motors (IE code)
- BS EN ISO 9001: Quality management systems
- BS EN ISO 14001: Environmental management systems

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FUSE RECYCLING

BEAMA Fuse Recycling Ltd has been set up to enable every component of blown or surplus fuse-links to be effectively re-used instead of contributing to landfill.

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www.beama.org.uk