Guide to

Low Voltage

Switch and Fusegear Devices

C O N T E N T S

1 INTRODUCTION

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.

In a letter from W H Preece to the Society of Telegraph Engineers in 1887, it was stated that fuses had been used to protect cables since 1864. The earliest enclosed fuse links were patented by Thomas Edison in 1880. These were air-filled, the primary purpose of the glass envelope being to prevent molten droplets falling from the element and to relieve the tensile strain on the element. In 1890, W M Mordy, patented the first cartridge fuse link filled with arc-quenching materials. The device comprised a copper foil or wire conductor enclosed in a glass tube filled with chalk, sand, marble or some other granular material.

Fuse technology has come a long way since the early days of Edison and Mordy. More recent developments have been incremental, with the emphasis on better performance, increased safety and 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 distribution boards, together with switchgear design, are evolving to meet today's increasing technological demands.

This guide starts from the fuse and develops through the various switches. It is intended as an introduction to fuse and switchgear solutions available from BEAMA Installation Sector members.

2 FUSES

Fuses are an important component in almost every electrical installation, protecting both equipment and personnel. Fuse links and fusegear are manufactured under Quality Systems which are independently assessed to BS EN ISO 9000 Quality management and quality assurance standards, and many fuse links carry the ASTA 20 endorsement. 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 electromechanical and thermal properties of the element, body materials and components, together with sand compaction, are all critical factors in manufacture.

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.

RANGE OF FUSELINKS TO BS EN 6029

Fuse Link – A device with a strip or element of easily melted metal placed in an electrical circuit so as to interrupt an excessive current by melting. The modern fuse normally comprises a fusible element enclosed in a ceramic tube filled with a granular arc-quenching material. The fuse link may be fitted into a fuse holder, or fuse-combination unit (FCU) to provide protection for distribution systems.

HRC or HBC Fuse Link – High Rupturing Capacity or High Breaking Capacity denotes the ability of a fuse link to interrupt extremely high fault currents.

Current Limiting Fuse Link – A fuse link that, during its operation, limits the circuit current to a value much lower than the peak value of the prospective current. In practice, the terms HRC and Current Limiting are synonymous.

Full Range (General Purpose) Fuse Link – A fuse link with a full range breaking capability, i.e. capable of interrupting all currents from rated breaking current generally down to the minimum fusing current.

Back-up Fuse Link – A fuse link with partial breaking capacity incorporating a minimum breaking current.

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.

Fuse Bank – A configuration of fuse holders mounted in series on to a back strap and connected to an insulated busbar comb.

Fuse Board – A fuse bank or fuse banks mounted in an enclosure together with ancillary equipment (earth/neutral bars) protecting a number of individual circuits.

Fuse-Combination Unit (FCU) – 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).

2.2 Fuse Link Ratings

Voltage – The maximum nominal voltage that the fuse link is designed to interrupt. The fuse link may have an a.c. rating , a d.c. rating or both.

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

Dual Rating – Commonly used in the UK to designate the current rating of a motor fuse.

Breaking Capacity – The maximum fault current that the fuse link has been tested to interrupt. The fuse link may have an a.c. rating, a d.c. rating or both.

Conventional Fusing Current I_f – The value of current which causes operation of the fuse link within the ‘conventional time’ (usually 1.6 x I_n); previously known as “minimum fusing current”.

Conventional Non-fusing Current (I_{nf}) – The value of current which the fuse will carry for the conventional time without operating (usually 1.25 x I_n).

Minimum Breaking Current – The minimum value of current that the fuse link can satisfactorily interrupt.

Power Dissipation – The power released in a fuse link carrying rated current under specified conditions.

Conventional Time – The time specified for which the fuse shall carry non-fusing current or operate within for fusing current. Conventional times are:

1 hour for ratings of 63A and below

2 hour for ratings above 63A and up to 160A

3 hours for ratings above 160A and up to 400A

4 hours for ratings above 40A

Fusing Factor – A term used historically 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 1.25

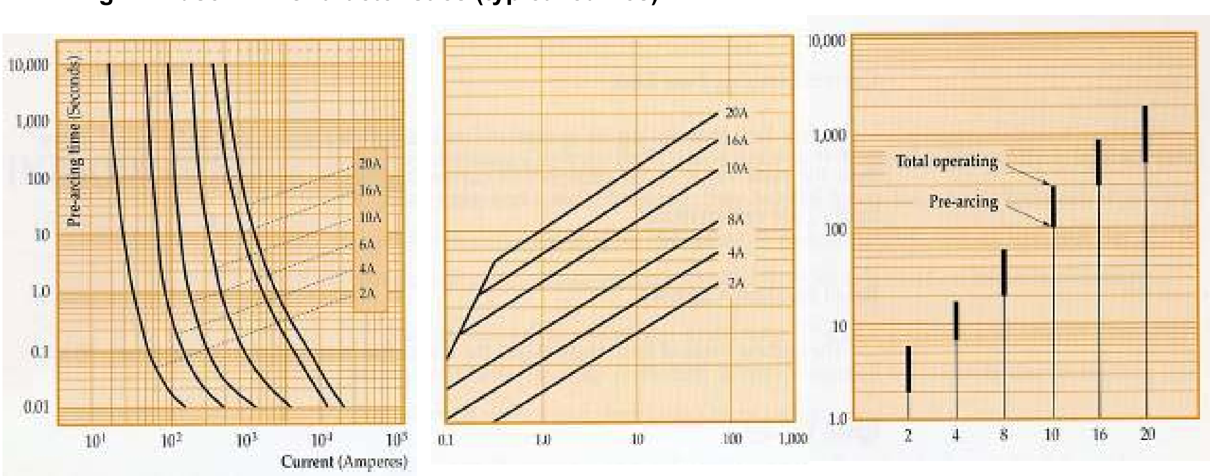
Class Q1 Fusing factor 1.25-1.5. The most common, still referred to in some customer specifications. Similar in performance to Utilization Class gG

Class Q2 Fusing factor 1.5-1.75

Class R Fusing factor 1.75 and above which was generally referred to as a motor starting fuse. Similar in performance to Utilization Class aM.

2.3 Fuse Link Characteristics

Fig. 1. Fuse Link Characteristics (typical curves)



Time Current Characteristic **Cut-off Characteristic** **Let Through Characteristic (I^2t)**

Time Current Characteristics – A curve detailing the pre-arcing or operating time as a function of prospective current. The time current curve has a basic tolerance of ±10% in terms of current; this is insignificant when compared with other protective devices.

Cut-off Characteristics – A curve detailing 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: The prospective current is expressed in kA rms, 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.

Let-through Characteristics (I^2t) – 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 in Amp^2 seconds.

2.4 Utilization Classes

The following Utilization Classes are identified for fuses:

gG Full range breaking capability, general applications

gM Full range breaking capability, motor circuit protection

aM Partial range breaking capability, motor applications

aR/gR Semiconductor protection, fast acting

gS Semiconductor protection including cable overload protection

2.5 The BS1362 Fuse

The UK uses a fused plug which must be fitted with a BS 1362 fuse. For domestic installations the use of the BS 1363 plug and socket system and the fitting of a BS 1362 fuse into a plug is a legal requirement under the UK *Plug and Socket Safety Regulations, 1995*.

With a correctly fused BS 1363 plug, the flexible cable connected to equipment is always fully protected against the effects of overload or small overcurrents as follows:

3A fuse protects $0.5mm^2$ cords
5A (6A) fuse protects $0.75mm^2$ cords
13A fuse protects $1.25mm^2$ cords

Protection against excessive damage by a short circuit is still achieved even if the smaller cord sizes are inadvertently protected by a 13A fuse. In addition, it has been accepted in the UK that some marginal damage to small flexible cords is tolerable under short circuit conditions, for example where a $0.22mm^2$ cord is used with a 13A BS 1362 fuse.

The use of BS 1362 fuses to protect flexible cords or cables from overload conditions and from fault conditions such as short circuits, earth faults and overcurrents has long been an essential feature in the UK.

BEAMA Installation Sector members who manufacture BS 1362 fuses and BS 1363 accessories in the UK recognise the importance of a comprehensive system of British Standards, third party approval and, above all, rigorous automated process control.

3 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 useful 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 – A 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 – A 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.

SWITCH DISCONNECTOR HIGH IP RATING TO BS EN 60947-3

Switch-disconnector – A switch which, in the open position, satisfies the isolating requirements specified for a disconnector.

OPEN TYPE SWITCH DISCONNECTOR FUSE (FUSE COMBINATION UNIT) TO BS EN 60947-3

Fuse-combination unit – 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.

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

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

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

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

RANGE OF SWITCH DISCONNECTOR FUSES TO BS EN 60947-3 LOW CURRENT

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

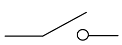
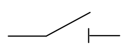
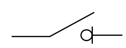
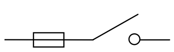
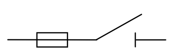
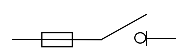
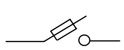
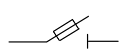
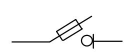
SWITCH DISCONNECTOR (FUSE) MAY BE FITTED WITH FUSES HIGH CURRENT RATING TO BS EN 60947-3

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

Whilst at first sight these definitions may appear complex and confusing, there is a 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.

Function		
Making and breaking current	**Isolating**	**Making, breaking and isolating**
Switch 	Disconnector 	Switch-disconnector 
Switch-fuse 	Disconnector-fuse 	Switch-disconnector-fuse 
Fuse-switch 	Fuse-disconnector 	Fuse-switch disconnector 
NOTE 1 – All equipment may be single-break or multi-break. NOTE 2 – Symbols are based on IEC Publication 60617-7.		

It is important to note that the definitions do not indicate whether the device is capable of being isolated at both ends of the fuse. Where this is not the case, adequate marking of the line/load terminals is essential for safe use.

3.2 Category of Duty

Switching devices are classified according to Utilization Category, or Category of Duty, as detailed below:

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.
AC21/DC21	Switching of resistive loads including moderate overloads Suitable for purely resistive type loads. Device can switch 150% of its rated current under fault conditions.
AC22/DC22	Switching of mixed resistive/inductive loads, including moderate overloads Suitable for mixed resistive/inductive loads. Device can switch 300% of its rated current under fault conditions.
AC23/DC23	Switching of highly inductive loads Devices complying with AC23/DC23 are 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 Annex A of BS EN 60947-3.

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 manufacturer's advice should be sought.

3.3 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.

Standard BE EN 90947-3 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 a small device (say up to 100A); once a week for larger devices.

Infrequent (B): Once a week for smaller devices; once a month for the larger devices.

4 FUSE ASSEMBLIES

4.1 Fuse Holders

Modern fuse holders for the UK market are designed to meet the requirements of either BS 88: Part 2 or BS 88: Part 6. It is a fundamental requirement that they are completely safe and that live contacts cannot be touched. The fuse holders normally consist of a base and a carrier; the base contains the main incoming and outgoing terminals to which cable terminations can be made. These terminals are shielded to prevent accidental contact. The carrier has provisions to take the appropriate fuse link and its removal from the base ensures fuse link replacement can be carried out safely with no danger to personnel. The mouldings which carry the base contacts and fuse link are usually moulded from high quality, flame retarding, synthetic materials.

TYPICAL FUSEHOLDERS TO BS 88:PART 2

Fuse holders are the most common means of utilising fuse links in industrial environments. Two main types are employed:

BS 88:Part 2 – These are for use with bolted tag type fuse links up to 400A
BS 88:Part 6 – These are intended for use with offset blade tag fuse links up to 63A

4.1.1 Protection against electric shock

It is common practice, for safety reasons, to have shrouded base and carrier contacts so that no "live" metal is exposed in the fuse base when the fuse carrier is withdrawn, nor is it possible to contact live metal during insertion or removal of the fuse carrier.

BS 88 identifies three states of the fuse where personnel must be protected against electric shock. These states are as follows:

A) When the complete fuse is properly mounted, installed and wired with fuse base, fuse link and, where applicable, gauge piece, fuse carrier and enclosure forming part of the fuse (normal service condition);

B) During replacement of the fuse link;

C) When the fuse link and, where applicable, the fuse carrier is removed.

Both types of fuse holder defined above provide a degree of protection IP2X in all of the three states, thereby providing compliance with BS 88.

4.1.2 Cable Connection

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

Front/Front:	Cable entry at top and bottom of the fuse base.
Back Stud:	Rear 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 to a busbar at the other end.

Fuse holder/fuse link combinations are widely used within industry for the protection of various circuits and can be used either as:

- Stand-alone items incorporated into various systems.
- Incorporated into Distribution/Control Panels and Boards.

4.2 Fuse Banks

Fuse holders mounted on to a rear fixing rail or strap and having their incoming terminals connected together by a common busbar are available as 4, 6, 8, 10 or 12 way fuse banks, the figure denoting the number of fuse holders mounted on the fuse bank. Complementary neutral bar and earth bar arrangements are available to complete the package.

TYPICAL FUSE BANKS FORMING A STANDARD PART OF A DISTRIBUTION FUSE BOARD

In order to facilitate their use, single pole fuse banks, neutral bar and earth bar arrangements can be incorporated into distribution systems, control panels and separate enclosures to provide an efficient means of distribution.

4.3 Distribution Fuseboards

Fuseboards, together with the relevant neutral bar and earth bar, can be assembled into high quality metal enclosures as complete factory built assemblies. These assemblies are more commonly referred to as Distribution Fuseboards. They meet the requirements of BS 5486:Part 11 Specification for particular requirements for fuseboards or, alternatively, BS EN 60439-3 Particular Requirements for low-voltage switchgear and controlgear assemblies intended to be installed where unskilled persons have access to their use – Distribution Boards, but could be tested to the European standard for low-voltage switchgear and controlgear assemblies, BS EN 60439 Part 3. They provide an excellent 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.

DISTRIBUTION FUSE BOARD TO BS 5486:PART 11

In general, all distribution fuseboards must 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. The use of such a device simplifies the task of selecting a fuse link to provide discrimination.

All of these units together with switch-disconnector-fuses can be incorporated into standard distribution switchboard systems or used in purpose-built systems to suit a particular application. A typical example of this would be a motor control centre comprising a main incoming isolating device, distribution board and switch-disconnector-fuses.

4.4 IP (International Protection) Codes

Selection of enclosures should begin with a consideration of the protection required in accordance with BS EN 60529:1992 *Specification for degrees of protection provided by enclosures (IP code)*. This will take account of the installation location as follows:

a) what persons are likely to use, or come into contact with, the equipment
b) suitability of the enclosure for the working environment for which it is intended.

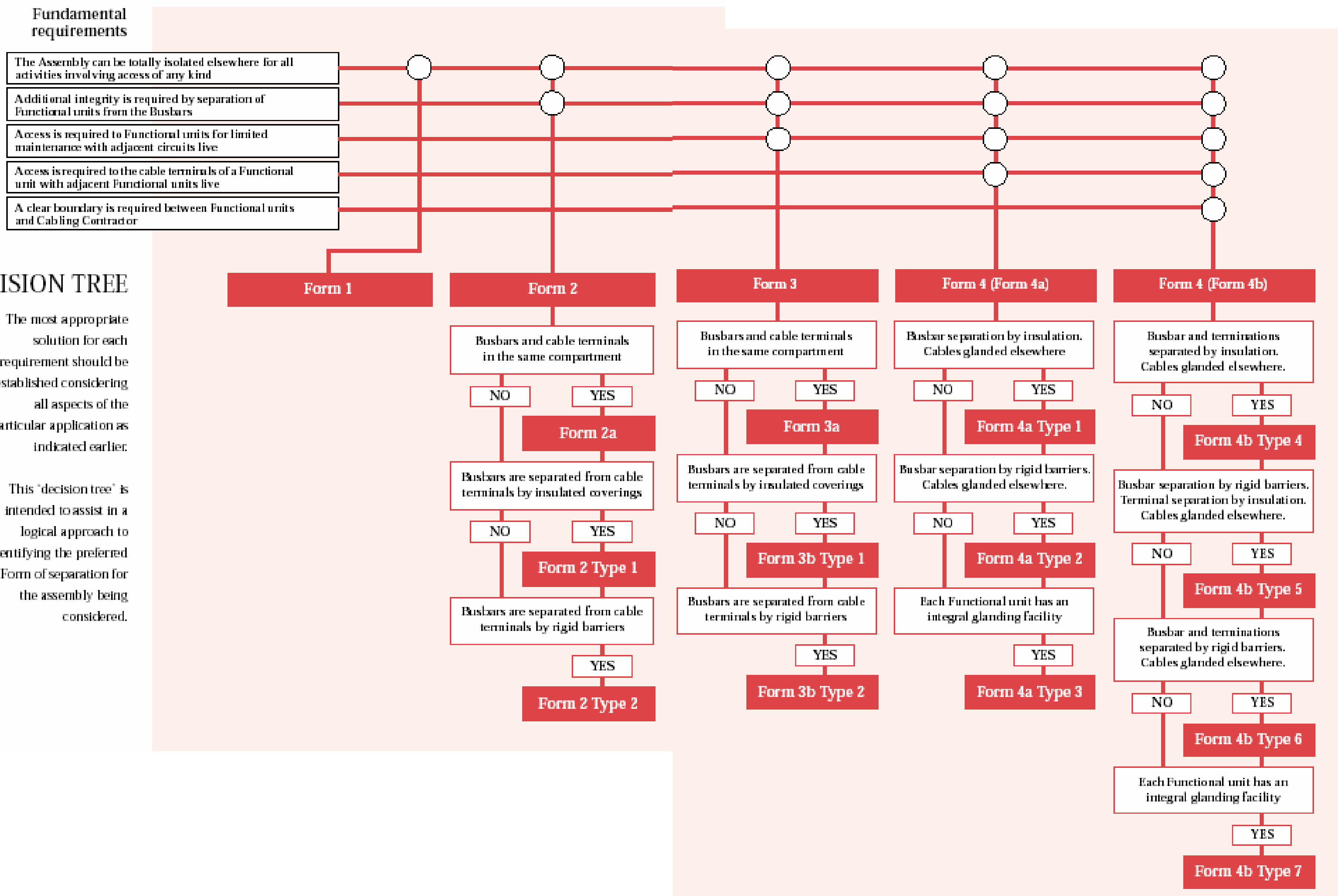
The specified/claimed IP Code applies when the equipment/enclosure is properly installed, according to the manufacturer's instructions. Further detailed information on the definitions and application of IP Codes is included in the *Guide to the 'IP' Codes for Enclosures,* available from BEAMA.

4.5 Forms of Separation

BS EN 60439 Part 1 describes a system for classifying the various forms of separation provided in low voltage switchgear and controlgear assemblies. These are provided for:

- Protection against contact with hazardous parts belonging to adjacent functional units.
- Protection against the passage of solid foreign bodies from one unit of an assembly to an adjacent unit.

Separation is achieved by means of barriers or partitions of metallic or non-metallic material and is subject to agreement between manufacturer and user. These barriers or partitions may form individual separate compartments or enclosed spaces.



12 DECISION TREE

The most appropriate solution for each requirement should be established considering all aspects of the particular application as indicated earlier.

This 'decision tree' is intended to assist in a logical approach to identifying the preferred Form of separation for the assembly being considered.

5 GENERAL APPLICATION OF FUSE LINKS IN SWITCHABLE EQUIPMENT

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 can 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.

5.4 Ambient Temperature

Fuse links are thermal devices. If they are to be operated at full load for long periods at elevated ambient temperatures 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.

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

a) Temperature rise

An increase in average ambient temperature will result in a relatively small increase in the temperature rise of the fuse link

b) Time/Current Characteristics

For relatively long operating times there will be a decrease, usually small, in the operating times of fuse links at elevated ambient temperatures. At high levels of fault current, where fuse links are operating under adiabatic conditions, the characteristics will be unaffected by high ambient temperatures.

5.5 Discrimination

Discrimination is the ability of protective devices to operate selectively to ensure that, in the event of a fault occurring, only the faulty circuit is isolated from the system, allowing healthy circuits to remain on load.

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

a) Discrimination 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. Discrimination 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 +/- 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 does not exceed the pre-arcing energy (I^2t) of the major fuse link at the applied system voltage.

In service, the short circuit fault conditions encountered are usually less exacting than those produced in proving tests on fuse links and associated equipment. BS 88:Part 1 states that fuse links experience fault currents which produce pre-arcing times longer than 0.01 second in most cases and, on that basis, fuse links complying with the standard are deemed to discriminate with each other when the ratio between the current ratings of “major” and “minor” fuse links is 1.6:1

Whilst the BS 88 statement is reasonable in relation to 240V applications, fault currents in major installations can be much greater. However, even in the latter cases, conditions are less onerous than those encountered in test stations (in particular, the circuits are usually three-phase with relatively high power factors).

In practice, therefore, the total I^2t values of HRC fuse links are usually significantly less than those published by manufacturers. Consequently the fuses will discriminate with each other at fault levels up to 80kA at 415V. 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.

Fig. 4: Discrimination between fuse links in a typical three-phase distribution system (shown single line). With properly selected HRC fuse links "minor" fuse link C operates and "major" fuse links A & B remain unaffected.

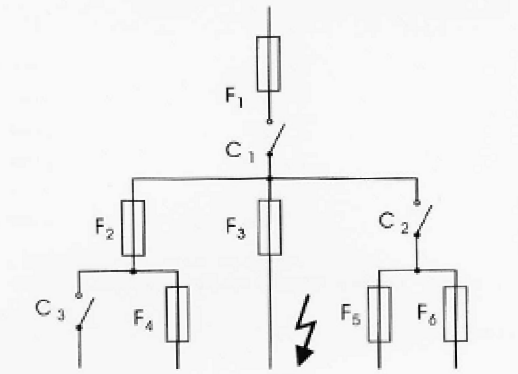


Figure 4 – Discrimination – General network diagram

b) Discrimination 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. This factor assists selection for discrimination where the major protective device is electro-mechanical and the minor protective device is a fuse link. All that is necessary to achieve discrimination is to ensure that the tripping time characteristic curves of the electromechanical device do not intersect with the time current characteristics of the fuse link. This condition is achieved automatically in most cases where the upstream electromechanical device would be expected to be controlling more than one sub-circuit protected by fuse links and its current rating will be determined accordingly.

6 APPLICATION OF FUSE LINKS TO SPECIFIC EQUIPMENT

6.1 Cable Protection

6.1.1 Complete cable protection

By using a 'gG' fuse link of current rating equal to, or less than, the cable rating, both overload and short circuit protection is easily achieved in accordance with BS 7671 (The *IEE Wiring Regulations, Sixteenth Edition*) Clause 433-02.

6.1.2 Protection of cables against short circuit faults

In some circuits (e.g. motor circuits) it is not economical to match fuse links and cable ratings to provide complete cable protection in the manner described previously, because the circuits produce significant overcurrents during switching. In such cases the fuse links are chosen to withstand the transient conditions and provide only short circuit protection to the associated cables and other circuit components. Overload protection is provided by other means. In a motor circuit, for example, the contactor and its overload relays afford overload protection to motor windings and cables; the fuse links are chosen to protect all the circuit components against damage when a short circuit fault occurs.

6.1.3 Back-up protection

Because of their current limiting capability fuses can provide, when connected in series, back-up protection to other overcurrent protective devices, for example circuit-breakers. With the correct co-ordination with the fuse the limitation of let through energy can allow such devices to be used in applications where the short-circuit fault level exceeds the device rating. Such an arrangement is recognised by BS 7671 Regulation 434-03-01.

6.2 Motor Circuit Protection

6.2.1 AC motors

All BS EN 60269, utilization category gG, fuse links have an excellent ability to protect motor circuits. When selected correctly, they not only withstand motor starting surges and full load currents without deteriorating but also provide superior short circuit protection to associated motor starter components.

Leading manufacturers of motor starters have recognised this and can offer Certified Type 2 coordination to BS EN 60947-4 by using BS 88 fuse links in combination with their chosen contactors and overload relays. Coordination test reports are available from all reputable manufacturers of motor starters, using short circuit protection fuse links to BS 88 and IEC 60269. To obtain Type 2 coordination for a motor/starter combination selected to the starter manufacturer’s recommendation, it is only necessary to use the lowest rating fuse link capable of handling normal full load current and starting surges, without deterioration. This is done with the aid of fuse link selection tables which are readily available from most leading fuse link manufacturers.

Type 2 coordination information and rules are available in IEC 61459

Fuse links are selected to withstand motor starting surges, typically 7 x full load current, for the run-up period, normally 10 seconds, in the case of direct on line (DOL) start motors and 3.5 x full load current for a run up period, normally taken as 20 seconds, for assisted start conditions.

Suitable adjustments to the ratings may be necessary if any of the following conditions occur singly or in combination:

- Starting currents in excess of the assumed ones
- 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).

gM type 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 electrical characteristic to which the fuse conforms. These two ratings are normally separated by the letter M which defines the application. For example a 20M32 fuse link is intended for use in the protection of motor circuits and has a maximum continuous rating of 20A but the electrical characteristics of a 32A rating. This means that the associated equipment need only be rated at 20A thereby providing significant economies against 32A 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 giving the maximum fuse link rating which will give short circuit protection for a particular cable size. If full protection of the cable is 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 starter combination. Correct selection of the fuse link rating, using the criteria given above, will provide coordination between all of the main components of the system.

6.2.2 DC motors

With the majority of d.c. motors there is no associated high starting surge. 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 protection for the motor. It is important to ensure that the d.c. voltage rating of the fuse link is sufficient for the application as a.c. and d.c. voltage ratings for protective devices normally differ.

6.3 Transformer Protection

Fuse links used on the primary side of a transformer should be selected to withstand the transformer magnetising inrush current (generally assumed to be around 10-12 x FLC for 0.1 seconds) in addition to any permissible overloads. In most cases a fuse link rating of 150-200% of the primary current rating of the transformer will fulfil the above requirements.

6.4 Capacitor Protection

Power factor correction capacitors need to have fuse links capable of withstanding the transient currents associated with switching as well as the capacitor tolerance and generated harmonics. Selection of a fuse link of 1.5-2 x capacitor FLC will usually be suitable. It should be noted that it is necessary to take into account the heating effect of these capacitor current fluctuations when selecting ratings of associated switching devices and other components.

6.5 Semiconductor Device Protection

In order to provide protection for devices such as power electronic diodes and thyristors it is necessary to select fuse links that have a lower energy (I^2t) and let through current than the devices themselves. This information is usually readily available from device manufacturers. Industrial fuse links to BS EN 60269-2-1 do not normally meet these criteria and fuse links having high speed characteristics, as defined in BS 88 Part 4, have to be used. It should be remembered that these fast acting fuse links are intended primarily for short circuit protection of the semiconductor devices.

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 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 dependent upon the overall r.m.s. current value of the duty cycle. Selection of the next highest rating of fuse link will normally be sufficient to provide adequate protection.

6.7 Household Protection

Fuse links are selected and applied to provide both short circuit and cable overload protection from the incoming house service cut-out through the consumer unit, which may contain fuse links or circuit breakers, right down to final circuit protection via the plug fuse link.

6.8 Fluorescent Lighting Protection

Fuse links protecting fluorescent lighting loads must be able to withstand the high inrush surges associated with the starter circuit which may be as high as 50 or 100 x full load current for less than 0.5ms. 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 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.

6.10 Protection of Instruments and Meters

Portable and switchboard instruments and meters are often used in locations where available fault currents are high. In such cases flash-over or failure in the instrument can cause extensive damage to the instrument and nearby equipment. It may also present a hazard to personnel. In order to avoid such occurrences, the use of a 2A rating HRC fuse link, in series with the potential (voltage) coil of the instrument, is recommended.

7 CURRENT STANDARDS

International standards are developed by the International Electrotechnical Commission (IEC) based on the consensus of world opinion. These are adopted, wherever possible, by the European Committee for Electrotechnical Standardisation (CENELEC) and issued as European Standards (ENs). Member countries are obliged to adopt them in unchanged form. In the United Kingdom, the British Standards Institution (BSI) issues them as national standards, as BS EN…   In certain cases existing BS standards are retained where there is no conflict of interest.

7.1 Fuses (BS EN 60269 and BS 88)

The harmonized European standard for fuses is BS EN 60269:*Low-voltage fuses* (IEC 60269:*Low-voltage fuses*) covering fuses incorporating enclosed current-limiting fuse links. It is divided into the following sections:

BS EN 60269-1 (IEC 60269): *General requirements* (Supersedes BS 88-2)

BS EN 60269-2 (IEC 60269): *Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application*) (Supersedes BS 88-2.1)

BS EN 60269-3 (IEC 60269-3): *Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications)*

IEC 60269-4: *Fuse links for the protection of semiconductor devices.*

In addition the following sections of BS 88: *Cartridge fuses for voltages up to and including 1000V a.c. and 1500V d.c.* apply:

BS 88-2.2: *Specification for fuses for use by authorized persons (mainly for industrial application)*

BS 88-4: *Specification of supplementary requirements for fuse-links for the protection of semiconductor devices* (IEC 60269-4)

BS 88-5: *Specification of supplementary requirements for fuse-links for use in a.c. electricity supply networks* (now incorporated into IEC 60269-2-1)

BS 88-6: *Specification of supplementary requirements for fuses of compact dimensions for use in 240/425V a.c. industrial and commercial installations* (now incorporated into IEC 60269-2-1).

7.2 Switchgear and Controlgear (BS EN 60947)

BS EN 60947: *Specification for low-voltage switchgear and* controlgear is divided into the following seven sections:

BS EN 60947-1:*General rules*

BS EN 60947-2:*Circuit-breakers*

BS EN 60947-3:*Switches, disconnectors, switch-disconnectors and fuse-combination units* (Supersedes BS 5419)

BS EN 60947-4:*Contactors and motor starters* (Supersedes BS 5424-1 and BS 4941-1)

BS EN 60947-5:*Control-circuit devices and switching elements* (Supersedes BS 4794-1)

BS EN 60947-6:*Multiple function equipment*

BS EN 60947-7:*Ancillary equipment*

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: *Specification for 13A fused plugs and switched and unswitched socket-outlets.*

BS 5486-11: *Low voltage switchgear and controlgear assemblies. Specification for particular requirements of fuseboards*

BS 7671: *Requirements for Electrical Installations (IEE Wiring Regulations Sixteenth Edition)*

BS EN 60439-3: *Specification for low-voltage switchgear and controlgear. Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access*

BS EN 60529: *Specification for degrees of protection provided by enclosures (IP code)*

BS EN ISO 9000: *Quality management and quality assurance standards*

More detailed technical details and explanations are available in IEC 61818.

8 SUMMARY

Modern high performance HRC fuse links are still unsurpassed in the field of protective devices and their versatility as stand-alone items, or integrated into switch-fuse-disconnect devices, ensures that the end user is obtaining the best protection available at an economic cost.

This guide has endeavoured to outline the typical application of these devices. The benefits to be gained by the use of modern HRC fuse links can be summed up by the six important reasons below:

1. **High breaking capacity and energy limitation** – In the event of a damaging short circuit the fault energy is severely restricted by rapid operation of the fuse link.

2. **Restriction of electromagnetic stress** – Modern HRC fuse links limit the amount of electromagnetic stress that would otherwise cause severe and costly mechanical damage to current carrying components.

3. **Proven reliability and non deterioration** – Unlike many other protective devices, BS 88 classified HRC fuse links, in practice, do not need replacing until one has blown. Proven technology and expertise ensure the highest quality, guaranteeing performance, reliability and years of uninterrupted service.

4. **Accurate discrimination** – In any well designed electrical installation, HRC fuse links are the main protective device in both primary and branch circuits. Modern HRC fuse links will discriminate with each other much more readily than other protective devices.

5. **Reliable short circuit and back-up protection** – High breaking capacity industrial fuse links are chosen by leading manufacturers of motor starters to provide ASTA Certified Type 2 coordination to IEC 60947-4.

6. **Low overcurrent protection** – The current and energy limiting properties of BS 88 fuse links ensures that the prospective short circuit currents are restricted to levels well within the overload capability of cables. PVC cables must have close excess current protection in accordance with rule 433-02 of the IEE Wiring Regulations.

Guide to

Low Voltage

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