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Introduction
In many commercial and industrial installations, circuits connected to main or sub-distribution boards may require local isolation, switching and additional protection. This is commonly found where machines, control cabinets, external supplies, temporary supplies and equipment requiring frequent maintenance are installed. In such cases, remote isolation and switching may be unsuitable in terms of practicality or safety in relation to the statutory requirements for Isolation & Switching. In addition to the Health and Safety at Work Act 1974 and the Electricity at Work Regulations 1989, recent European Directives have added to the safety requirements affecting electrical machinery and associated protection, control and operation systems. These additional statutory regulations are:

- Supply of Machinery (Safety) Regulations 1992.
- Electrical Equipment (Safety) Regulations 1994
- Construction (Design and Management) Regulations 1994
- Management of Health and Safety at work Regulations 1992
- Provision and Use of work Equipment Regulations 1998

Furthermore, BS 7671 addresses the safety requirements of isolation and switching in the following sections: 46,464,476 & 537. In addition, IEE Guidance Note No. 2 is concerned with the application of the requirements of BS 7671 relating to Isolation and Switching.

Standards
The relevant Standard that applies to this group of products is BS EN 60 947, which is entitled ‘Specification for low voltage switchgear and controlgear’. The Standard comprises seven parts, these are:

- Part 1 - General Rules
- Part 2 - Circuit Breakers
- **Part 3 - Switches, Disconnectors, Switch Disconnectors & Fuse Combination Units**
- Part 4 - Contactors & Motor Starters
- Part 5 - Electromechanical Control Circuit Devices
- Part 6 - Multiple Function Switching Equipment
- Part 7 - Ancillary Equipment

As can be seen from the list above, the part of the Standard applying to this product group is BS EN 60947-3. For enclosed MCCB products, BS EN 60947-2 will also apply. The Standard BS EN 60 947-3 supersedes British Standard BS 5419, which was withdrawn on the 1st March 1993.

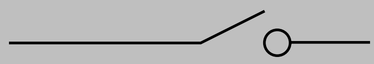
isolation & switching devices definitions

Definitions
The various definitions of functions and applications of devices to BS EN 60 947-3 can be found in the ‘International Electrotechnical Vocabulary’ and are reproduced in both the Harmonised Standard and the IEE Wiring Regulations.

Switch
Part 2 of BS 7671 gives the following definition:

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.

Switch Symbol



The symbol (‘O’) indicates the suitability of the device for making and breaking of a current-carrying circuit, in other words a functional switching device (load-break or on-load switch). However, it should be noted that this symbol does not indicate suitability for the purpose of isolation.

Current ratings
When selecting a switching device it is important to match the operational performance of the switch to the characteristics of the load to be switched. We need to look once more to BS EN 60 947-3 for further guidance, definitions of the current ratings of the switch will help us.

Current Rating Term	Symbol
Free air thermal current	I_{th}
Enclosed thermal current	I_{the}
Rated uninterrupted current	I_u
Rated operational current	I_e

I_{th} is the maximum value of test current used in temperature-rise tests on unenclosed equipment in a maximum ambient temperature of 40ºC, based on an eight hour duty-cycle. This value is relevant for applications where the switch is used in a customer’s own enclosure, such as by panel builders or OEMs.

I_{the} is again a maximum value of test current based on the above conditions, except that it is designed for equipment supplied in an enclosure or described as enclosed equipment in the manufacturer’s catalogue.

The eight hour duty-cycle covers applications where the contacts remain closed, but for not more than eight hours without breaking the current by operating the device. This is due to the possibility of dirt accumulating on the contacts, leading to progressive internal resistive heating.

I_u can be specified if the engineer is in any doubt as to the suitability of applying I_{the}. This uninterrupted duty is derived by applying a de-rating factor or by special design considerations such as the use of silver-tipped contacts. All Hager devices have silver-tipped contacts and can operate for a period of 6 years without maintenance.

I_e rated operational current. This takes into account four key factors and is applied only when the load requirements are less than or equal to the following ratings:

1. Rated operational voltage
2. Rated frequency
3. Rated duty
4. Utilisation category

I_e is not just a steady current rating, but relates directly to the switching capability of the device. Once a suitable thermal current rating has been selected, consideration should be given to the utilisation category.

Switching duty
Regulation 537-05-01 of BS 7671 states;
"Functional switching devices shall be suitable for the most onerous duty intended". Inspection engineers are specifically advised, in IEE Guidance Note 3, to verify the suitability of such devices for the intended load they are to control. Clearly, this should apply to all switching devices. This duty is known as the utilisation category .The first two designated letters denote whether the device is designed to switch alternating or direct current. The next two digits refer to the type of load to be switched i.e. resistive, resistive/inductive or inductive. The suffix letter indicates how often the switch is designed to be operated.

Example of utilisation category: AC23A

- AC Alternating Current
- 23 Defined Switching Category
- A Frequent Use
- B Infrequent Use

Common types of defined switching category:

- 20 Connecting & disconnecting under no load.
- 21 Switching of resistive loads.
- 22 Switching of mixed resistive & inductive loads.
- 23 Switching of highly inductive loads.

Typical applications for these duties are;

- AC21 - Heating elements (not tungsten); Cos ø = 0.95
- AC22 - Distribution board main switch
  - Compensated discharge lamps; Cos ø = 0.65
- AC23 - Panelboard main switch
  - Motors as required by : BS EN 60 204-1
    Cos ø = 0.35 for devices ≤ 100A
    Cos ø = 0.45 for devices > 100A

Under BS EN 60 947-3 these switches must also be capable of switching defined overloads. See below (shown as a % ratio if I_n):

Duty Category	Breaking Capacity	Making Capacity
AC21	150%	150%
AC22	300%	300%
AC23	800%	1000%

Manufacturers may assign more than one AC duty rating to their devices. For example an AC22 switch can be given a lower current rating when assigned to AC23 duty. Manufacturers may also assign a maximum kW power rating for motors or a kVAr reactive power rating for capacitors.

Frequency of use
Although the Standard does not specify what constitutes 'frequent' or 'infrequent' use, the EIEMA Guide to Switch and Fusegear Devices offers some guidelines.

- Frequent use, denoted by "A".
  Up to 5 switching operations per day for devices rated ≤ 100 A and up to one per week for devices with current ratings > 100A.

- Infrequent use, denoted by "B".
  No more than one switching operation per week for devices ≤ 100A and no more than one per month for devices with current ratings > 100A.

Switching function
Switching devices may also be required to operate in the event of an emergency. This can be separated into two areas defined as 'emergency stopping' and 'emergency switching'.

Emergency Stopping
Part 2 of BS 7671 gives the following definition:
"Emergency switching intended to stop an operation"
This operation could be required should somebody become entangled in machinery, for example a drill operative with their sleeve caught in the chuck of a drill.

Emergency Switching
Part 2 of BS 7671 gives the following definition:
"An operation to remove, as quickly as possible, danger, which may have occurred unexpectedly"

This danger can be from fire, electric shock and burns arising from the use of electrical energy. The design engineer must ensure that the correct control mechanism is used and is installed where readily accessible. Manufacturers usually offer two mechanisms, either a shunt trip or an undervoltage release (UVR), to control a circuit breaker, which could also be a non-automatic device in the form of a switch disconnector that may be remotely switched. The two mechanisms require very different conditions to operate. The shunt trip must be energised to operate, while the UVR is a fail-safe device which operates when de-energised. BS 7671 makes it very clear which device should be used.

"Where practicable a device for emergency switching shall be manually operated directly interrupting the main circuit. A device such as a circuit breaker or a contactor operated by remote control shall open on de-energisation of the coil, or another technique of suitable reliability shall be employed."

From this regulation it is clear that the use of a UVR is the preferred method. Further guidance on emergency switching can be found in BS EN 60204-1 Safety of Machinery. An example of this application could be to shut down cooking appliances in a commercial kitchen or air conditioning supplies to a section of a building, via auxiliary contacts in a fire alarm panel.
In industrial applications a machine supply could be shut down when an emergency stop button is activated.

Hager undervoltage release devices can be fitted to mcbs, non-auto mccbs and mccbs. These circuit breakers can be utilised as stand-alone devices in their own enclosure or as incomers to TP&N or panelboards, the mccbs can also be utilised with UVRs as outgoing devices on panelboards. This is especially useful where selective shutdown may be required, e.g. where a distribution board is feeding lighting circuits as well as power.

Testing to BS EN 60 947-3
In order to comply with the requirements of this Standard, sequential testing must be carried out. Specific performance characteristics have been grouped together into four test sequences:

1. General performance characteristics
2. Operational performance capability
3. Short-circuit performance capability
4. Conditional short-circuit current

Test sequence 1 -
General performance characteristics are designed to verify the following:

The unit will carry its rated thermal current I_{th} without overheating. This means that when the device is mounted in its enclosure (enclosed thermal current I_{the}) it can break the rated operational current at the voltage declared in the utilisation category. It has positive contact indication, or in other words, the contacts must be open when the handle is in the off position as indicated by the position and/or marking on the actuator.

Test sequence 1 is comprised of the following:
1. Temperature-rise test
2. Dielectric properties
3. Making and breaking capacities
4. Dielectric verification
5. Leakage current
6. Temperature-rise verification
7. Strength of actuator mechanism

Test sequence 2 -
Operational performance capability is a measure of the reliability/durability of the device which in practice is the total number of mechanical and electrical switching operations the unit can perform.

Further information can be found in table IV of BS EN 60 947-3. This is indicated by the suffix A or B on the declared utilisation category. Test sequence 2 would need to be carried out if the suffix A or B is to be added to the utilisation category.

Test sequence 2 comprises the following:
1. Operational performance
2. Dielectric verification
3. Leakage current
4. Temperature-rise verification

Test sequence 3 -
Short-circuit performance capabilities. This test determines how much current it will carry for a given length of time.

This is the ability to withstand the thermal and electrodynamic effects of short-circuit currents in devices that have no protective functions, making it necessary to declare the short-time withstand current, I_{cw}, for the device. A minimum test value is 12 times rated current for 1 second, but is often much higher. If the withstand time is less than 1 second, the manufacturer must state this in the technical data. In this test the withstand ability of a device being closed onto a fault is determined and given a value of short-circuit making capacity, I_{cm}.
Test sequence 3 comprises the following:
1. Short-time withstand current
2. Short-circuit making capacity
3. Dielectric verification
4. Leakage current
5. Temperature-rise verification

Test sequence 4 -
Conditional short-circuit current. This test determines how much current a device will carry for a given length of time, where the device is fitted with fuses.

This determines whether a device will withstand the declared short-circuit current and is capable of being closed onto a short-circuit of that magnitude when fitted with approved rated fuses. The declared short-circuit current for Hager fuse combination units is 50kA.

Test sequence 4 comprises the following:
- Fuse protected short-circuit withstand
- Fuse protected short-circuit making
- Dielectric verification
- Leakage current
- Temperature-rise verification

Isolation function
There has been a change in terminology with the term “Isolator” being replaced with “Disconnector” in BS EN 60 947-3. BS 7671 Part 2 defines the function of isolation as follows:

“A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy”

Disconnector
A mechanical switching device which, in the open position, complies with the requirements specified for the isolation function.In part 2 of BS 7671 it also states a “disconnector” is otherwise known as an “isolator”.

Disconnector symbol

The line perpendicular to the conductor (‘I’ symbol) above shows the suitability of the device for the purpose of isolation. However it should be noted that this symbol does not indicate suitability for use as a load-break switch (as no ‘O’ or ‘X’ symbol is present). A disconnector is capable of opening and closing a circuit when a negligible current is either 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-circuits.

Contact separation

The required gap between contacts of a switch being used to isolate a circuit can be determined by looking at the relevant product standard. Regulation 537-02-02 lists BS EN 1363-4, BS 3676, BS EN 60669-2, BS EN 60898, BS EN 60947-2, BS EN 60947-3, BS EN 61008-1 AND BS EN 61009-1 as applicable standards. It must not be assumed though that compliance with one of these standards automatically qualifies the product as a suitable disconnector.

Chapter 44 of BS7671 'Protection against overvoltage' details the minimum required impulse withstand voltages and impulse categories for products in tables.

Category	type of equipment
I	equipment intended to be connected to the fixed electrical installation where protection against transient overvoltage is external to the equipment, either in the fixed installation or between the fixed installation and the equipment. Examples of equipment are household appliances, portable tools and similar loads intended to be connected to circuits in which measures have been taken to limit transient overvoltages.
II	equipment intended to be connected to the fixed electrical installation e.g. household appliances, portable tools and similar loads, the protective means being either within or external to the equipment.
III	equipment which is part of the fixed electrical installation and other equipment where a high degree of availability is expected, e.g. distribution boards, circuit-breakers, wiring systems and equipment for industrial uses, stationary motors with permanent connection to the fixed installation.
IV	equipment to be used at or in the proximity of the origin of the electrical installation upstream of the main distribution board e.g. electricity meter, primary over current device, ripple control unit.

nominal voltage of the installation V	required minimum impulse withstand voltage kV			
	category IV (equipment with very high impulse voltage)	category III (equipment with high impulse voltage)	category II (equipment with normal impulse voltage)	category I (equipment with reduced impulse voltage)
230/240 277/480	6	4	2.5	1.5
400/690	8	6	4	2.5
1000	values to be determined by system engineer or, in the absence of information, the values for 400/690 can be chosen.			

BS EN 60947-1 requires that a contact gap of 3mm be used for category III equipment, and 5.5mm for category IV equipment. From the above table it could be assumed that rated impulse withstand voltages of 4kV and 6kV respectively would be adequate for a product deemed suitable as a disconnector. These tables are only intended to verify the suitability of the insulation characteristics of the equipment. Table 14 of BS EN 60947-1 gives U_{imp} voltages of 5kV for category III and 8kV for category IV for switches to be used as disconnectors.

The environmental effects of pollution in the atmosphere on dielectric separation must also be considered. Four degrees of pollution are established for the purpose of evaluating clearances. Unless otherwise stated, equipment complying with BS EN 60947-3 is for use in pollution degree 3 which is defined when: "conductive pollution occurs, or dry non-conductive pollution occurs which becomes conductive due to condensation". BS EN 60947-1 states that equipment for use in industrial applications is generally for use in pollution degree 3 environments. When a switch is mounted in an enclosure, the degree of pollution may improve. However if there is persistent conductive pollution such as in swimming pool installation where chlorine is present in the air, an enclosure with an ingress protection rating of at least IP54 should be used, this environment would be classed as pollution degree 4. One final consideration to be addressed is the height of the installation above sea level. Due to the reduced dielectric strength of air at higher attitudes, the U_{imp} values are increased when testing as this is generally carried out at sea level, but must be valid for altitudes up to 2000 meters.

The impulse voltage test is one of the three key tests associated with the disconnector, the next test verifies the reliability of the 'contacts open' indication.

Regulation 537-02-04 states;
"The position of the contacts or other means of isolation shall be either externally visible or clearly and reliably indicated. An indication of the isolated position shall occur only when the specified isolation has been attained in each pole".

It is notable that the regulations do not specify that the disconnector should have a separate contact indication such as a mechanical flag connected to the moving contact.
BS EN 60 947-3 requires that where a separate contact indicator is not provided and the actuator is used, the strength and reliability of the indication of the contacts in the open position shall be tested.

This is known as the 3F test. The contacts are bolted together in the closed position in order to simulate a condition where the contacts have become welded together. A force of three times the normal operating force, subject to minimum and maximum values, is applied for 10 seconds. Once released the actuator must not indicate that the contacts are in the open position.

The third test is for leakage current. A disconnector is tested for leakage current at each test sequence. When the contacts are in the open position the device must not permit a leakage current of more than 2 milliamps.

Devices that perform an isolating function may be required for maintenance purposes. This may involve working on normally live parts or working on moving parts of machinery. Part 2 of BS 7671 gives two definitions for guidance.

Isolation.
A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy.

Mechanical maintenance
The replacement, refurbishment or cleaning of lamps and non-electrical parts of equipment, plant and machinery.

When selecting an isolating device for mechanical maintenance it should be noted that it must be able to switch the full load current as required by Regulation 537-03-04. The reason for this is that persons authorised to perform this function may not be electrically competent and therefore may use the disconnector whilst the load is still connected.

It may be necessary to be able to lock off the disconnector. The facility to be able to lock off the disconnector can also be a means of preventing...

- unintentional reclosure resulting from mechanical shock or vibration.
- unauthorised or inadvertent operation

Once it has been established which type of device will be required, the next step is to decide how many poles to switch. Guidance on this can once again be found in BS 7671.

Regulation 537-02-01 states.
"Except as detailed by Regulation 460-01-04, the devices for isolation shall effectively isolate all live supply conductors from the circuit concerned."

One particular area of confusion concerning isolation is that of whether or not to break the neutral conductor.
Regulation 460-01-04 allows, in TN-S and TN-C-S systems, for the neutral conductor not to be isolated, although by definition a neutral is a live conductor. In TN systems the neutral conductor remains equal to or close to the potential of any exposed- or extraneous-conductive-parts within the equipotential zone. This exclusion only applies to TN systems supplied in accordance with The Electricity Supply Regulations 1988 as amended. TT or IT systems however do require isolation of the neutral conductor. The requirement to switch the neutral on single phase TN systems is different and Regulation 476-01-03 details an exception to the general rule.

Requirements to switch the neutral conductor

System	Single Phase	Three Phase
Main Switch		
TN-C-S	Yes	No
TN-S	Yes	No
TT	Yes	Yes
Downstream Isolation		
TN-C-S	No	No
TN-S	No	No
TT	Yes	Yes

Regulation 476-01-03 states.
"A main switch intended for operation by unskilled persons e.g. of a household or similar installation, shall interrupt both live conductors of a single-phase supply."

There are however certain places where neutral isolation is still required and further guidance can be found in 'guidance notes 2 Isolating and Switching'. The Electricity at Work Regulations, Regulation 12, requires that a risk assessment be carried out if the neutral is to remain unswitched, however in TN systems the risk of danger rarely exists.

The focus so far has been confined to devices conforming to BS EN 60 947-3. However, the function of isolation can be provided frequently by other devices. The requirements for disconnectors are held in BS EN 60 947-1 and therefore the same requirements can apply to Circuit Breakers covered by BS EN 60 947-2. The symbol for a circuit breaker shows that the perpendicular line is present (⊣ symbol) indicating its suitability as a disconnector. The Hager range of mccbs have a utilisation category of AC23A.

Circuit breaker symbol

Not all devices used as disconnectors are manufactured to BS EN 60 947 and therefore the design engineer may need to look to other standards for clarification of their suitability for the purpose of isolation. Two such devices are RCCBs and MCBs.

BS EN 61008 residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) states that within the scope of the present Standard RCCBs are considered suitable for isolation (subject to compliance with relevant sub-clauses).

BS EN 60 898 Specification for circuit breakers for overcurrent protection for household and similar installations states. Circuit-breakers within the scope of this standard are considered as suitable for isolation (subject to compliance with relevant sub-clauses)

Protection
Devices to BS EN 60 947-3 may include fuses for overcurrent protection. The use of motor rated fuse links in some cases can reduce the size and cost of the switchgear.

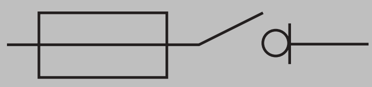
Fuse
A device which by fusing one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for sufficient time. The fuse-link comprises all the parts that form the complete device.

Combining functions
The wiring regulations permit the use of a single device to be used for more than one function.

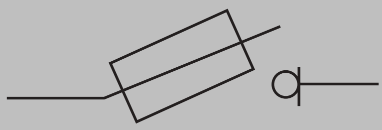
Regulation 537-01-01 states.
"Isolating and switching devices shall comply with the appropriate requirements of Regulation 537-02 to 537-05. A common device may be used for more than one of these functions if the appropriate requirements for each function are met."

The Hager range of switch disconnectors switch disconnector fuses and fuse combination switches , are typical examples of devices that can suit more than one function.

Switch fuse disconnector



Fuse-switch disconnector



Fuse combination switch

Devices in which the fuse does not form part of the moving contact are generally maintenance free. All Hager switches have silver contacts, and if installed in suitable damp-proof and dustproof enclosures and selected in accordance with the requirements of BS EN 60 947-1&3 and BS 7671, these devices can operate for a period of six years without maintenance. Other types of device which will perform the same functions, with the fuse forming part of the moving contact, generally require maintenance.

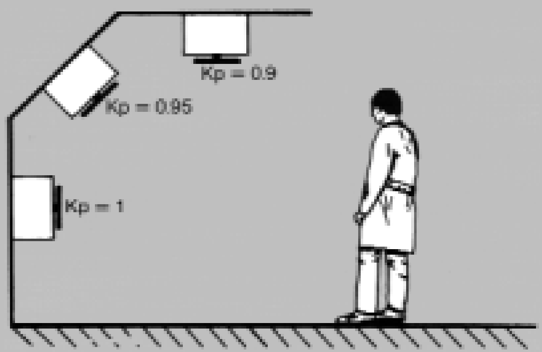
Specific application considerations
While it is important to take into account the parameters of the tests to achieve these ratings, The installation conditions should not be ignored as they could be crucial if the switch is to function correctly and consistently. One area which is constantly overlooked is conductor operating temperature. The terminal temperature rise limit for devices to BS EN 60 947-1 is 70ºK and is based on the use of PVC cables. Regulation 512-02-01 says that equipment should not be connected to conductors that operate at a temperature exceeding 70ºC unless the manufacturer confirms its suitability. Tabulated current ratings (I_t appendix 4 BS 7671) for cables with thermosetting insulation such as XLPE should be selected from the equivalent PVC tables, or the formula in appendix 4 can be applied i.e. a correction factor of 0.81. Other factors may also need to be taken into consideration and the device derated accordingly. These are;

- Ambient temperature above 40°C
- Switch mounting and orientation
- High frequency

Correction factor for ambient temperature

0.9	40°C < t_a ≤ 50°C
0.8	50°C < t_a ≤ 60°C
0.7	60°C < t_a ≤ 70°C

Correction factors for switch orientation



e.g. 100A switch mounted on ceiling. New rating is 100 x 0.9 = 90A

Correction factor due to frequency

0.9	100 Hz < f ≤ 1000Hz
0.8	1000 Hz < f ≤ 2000Hz
0.7	2000 Hz < f ≤ 6000Hz
0.6	6000 Hz < f ≤ 10000Hz

Regulation 512-02-01 states;
Every item of equipment shall be suitable for:

(i) the design current, taking into account any capacitive and inductive effects, and

(ii) the current likely to flow in abnormal conditions for such periods of time as are determined by the characteristics of the protective devices concerned. Switchgear, protective devices, accessories and other types of equipment shall not be connected to conductors intended to operate at a temperature exceeding 70ºC at the equipment in normal service, unless the equipment manufacturer has confirmed that the equipment is suitable for such conditions.

Starting currents on motor circuits
Motors that are subject to frequent starting can produce a cumulative heating effect of the switch contacts. The effects can be termed the 'equivalent thermal current (I_{thq})'. Starting current and duration can vary widely dependant on motor inertia, the following table and formula can be used to determine the suitability of a switch for the application.

start up type	peak current	duration of starting current	number of start ups per hour	derating factor K
D.O.L ≤ 170kW	8 x I_n	4 seconds	n > 10	$\frac{\sqrt{n}}{3.16}$
Star - Delta	2.5 x I_n	6 seconds	n > 85	$\frac{\sqrt{n}}{9.2}$
High inertia motors (fans, pumps)	8 - 12 x I_n	10 seconds	n > 2	$\frac{\sqrt{n}}{1.4}$

$I_{thq} = I_n \times K$ (switch $I_{th} \geq$ calculated I_{thq})

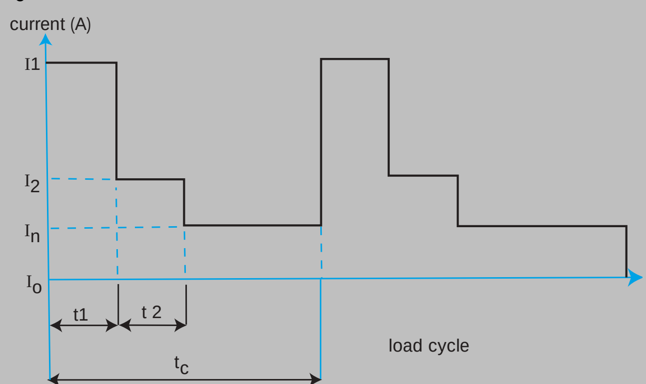
Example
A sump pump operated by a float switch operates once every 2 minutes giving 30 startups per hour, the running current is 7.5A.

$K = \sqrt{30}/1.4 = 3.91$ so $I_{thq} = 7.5 \times 3.91 = 29.34A$
Therefore a switch rated at 30A or more would be appropriate

Cyclic loads
Whilst it is necessary to ensure a switch is adequately rated to perform it's function consideration should also be given to prevent over specifying switching equipment if costs of equipment is important. Machinery in a manufacturing plant may perform various functions. An example could be a machine with a punching tool (45A for 8s), a spot welding operation (80A for 2 s) and a conveyor belt (20A continuous). This machine would normally be connected to one switching device, to ensure the switch is adequate the highest current using component could be used and in this example an 80A switch would be selected. A formula to calculate the equivalent thermal current can be used which could result in a smaller switch being able to be used.

$$I_{thq} = \frac{\sqrt{(I_1^2 \times t_1) + (I_2^2 \times t_2) + In^2 \times (tc - [t_1 + t_2])}}{tc}$$

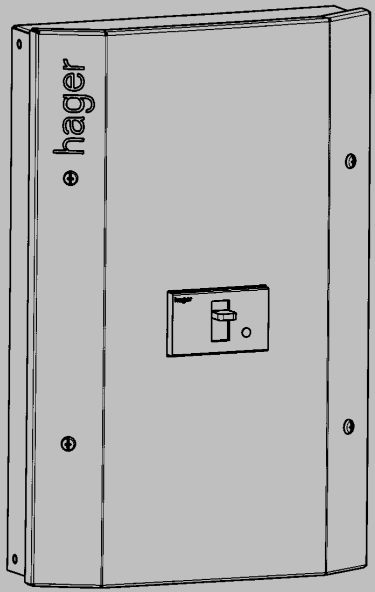
Where
I_1 = overload current
I_2 = possible intermediate overload
I_n = nominal operating current
t_1 & t_2 = respective duration in seconds of currents I_1 & I_2
t_c = cycle duration with the lower limit set at 30 seconds



$$I_{thq} = \frac{\sqrt{(45^2 \times 8) + (80^2 \times 2) + 20^2 \times (30 - [8 + 2])}}{30} = 35.12A$$

Therefore a 40A device would be suitable.

enclosed MCCB & Invicta FCS - dimensions

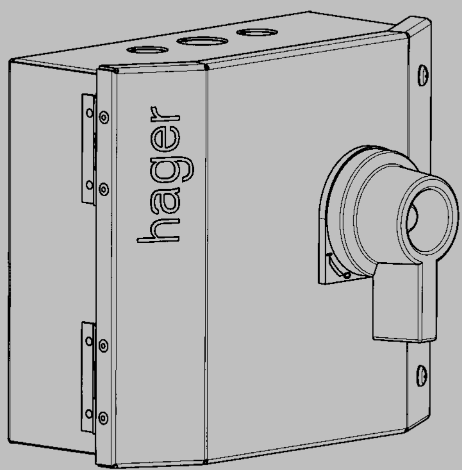


enclosed moulded case circuit breakers

cat. ref.	description	L	N	height	width	depth
JG25M	63A SPN	70mm	M8	420	267	83
JG26M	63A TPN	70mm	M8	420	267	83
JG27M	63A 4P	70mm	M8	420	267	83
JG27R	63A 4P + RCCB	70mm	M8	420	369	83
JG28M	100A SPN	70mm	M8	420	267	83
JG29M	100A TPN	70mm	M8	420	267	83
JG30M	100A 4P	70mm	M8	420	267	83
JG31M	125A SPN	70mm	M8	420	267	83
JG32M	125A TPN	70mm	M8	420	267	83
JG33M	125A 4P	70mm	M8	420	267	83
JG33R	125A 4P + RCCB	70mm	M8	420	369	83
JG34S	125A TPN non auto MCCB	70mm	M8	420	267	83
JG35S	125A 4P non auto MCCB	70mm	M8	420	267	83
JG36M	160A TPN	120mm	M10	660	334	97
JG37M	160A 4P	120mm	M10	660	334	97
JG37R	160A 4P + RCCB	120mm	M10	768	334	97
JG40M	250A TPN	120mm	M10	660	334	97
JG41M	250A 4P	120mm	M10	660	334	97
JG41R	250A 4P + RCCB	120mm	M10	768	334	97
JG42S	250A TPN non auto MCCB	120mm	M10	660	334	97
JG43S	250A 4P non auto MCCB	120mm	M10	660	334	97
JG44M	400A TPN	240mm	M10	870	384	117
JG45M	400A 4P	240mm	M10	870	384	117
JG45R	400A 4P + RCCB	240mm	M10	1000	384	117
JG46S	400A TPN non auto MCCB	240mm	M10	870	384	117
JG47S	400A 4P non auto MCCB	240mm	M10	870	384	117
JG48M	630A TPN	2x240mm	M10	1130	509	157
JG49M	630A 4P	2x240mm	M10	1130	509	157
JG50S	630A TPN non auto MCCB	2x240mm	M10	1130	509	157
JG51S	630A 4P non auto MCCB	2x240mm	M10	1130	509	157

All sizes are in mm

fused combination switches



cat. ref.	description	height	width	depth
JG04F	20A SPSN	200	234	116
JG01F	32A SPSN	200	234	116
JG05F	20A TPN	200	234	116
JG02F	32A TPN	200	234	116
JG06F	20A TPSN	200	234	116
JG03F	32A TPSN	200	234	116
JG10F	63A SPSN	312	300	124
JG11F	63A TPN	312	300	124
JG12F	63A TPSN	312	332	124
JG16F	100A SPSN	352	342	133
JG17F	100A TPN	352	342	133
JG18F	100A TPSN	352	378	133
JG19F	125A SPSN	452	384	149
JG20F	125A TPN	452	384	149
JG21F	125A TPSN	452	434	149
JG22F	160A SPSN	452	384	149
JG23F	160A TPN	452	384	149
JG24F	160A TPSN	452	434	149
JG25F	200A SPSN	603	475	187
JG26F	200A TPN	603	475	187
JG27F	200A TPSN	603	535	187
JG30F	315A TPN	491	615	308
JG31F	315A TPSN	491	680	308
JG32F	400A TPN	491	615	308
JG33F	400A TPSN	491	680	308
JG36F	630A TPN	513	670	351
JG37F	630A TPSN	513	750	351

All dimensions are in mm and exclude the handle.
Add 70mm to the depth to allow for the handle (41mm for 20 and 32A ratings)

cable extension boxes

cat. ref.	description	height	width	depth
JG41E	315 / 400 TPN	250	615	308
JG42E	315 / 400 TPSN	250	680	308
JG43E	630 TPN	400	670	351
JG44E	630 TPSN	400	750	351

fuse combination units - technical information

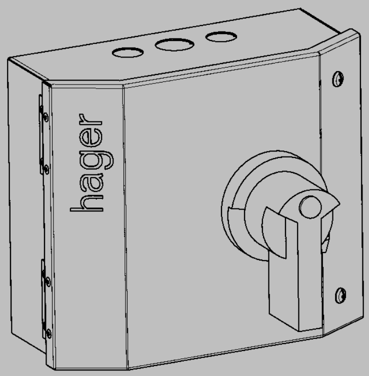
thermal current I_{th} (40°C)	20A	32A	63A	100A	125A	160A	200A	315A	400A	630A*
fuse size: BS	A1	A1	A2-A3	A4	A4	B2	B2	B3	B4	C1-C2
rated insulated voltage										
U_i (V)	690	690	750	750	750	750	750	1000	1000	1000
impulse voltages U_{imp}	8000	8000	8000	8000	8000	8000	8000	8000	8000	1200
operational current I_e (A) 400V ac AC-23A/AC-23B	20	32	A B 63 63	A B 100 100	A B 125 125	A B 160 160	A B 200 200	A B 315 315	A B 400 400	AC22B 630
Motor power (kW) 400V ac	9	15	30	51	63	80	100	160 160	220 220	355 355
reactive power 400V ac (kVAR)	15	45	25	45	55	60	75	125	150	2x125
overload capacity short-circuit with fuses (kA Rms)	50	50	50	50	50	50	50	50	50	50
fuse rating (A) BS 88	20	32	63	100	125	160	200	315	400	630
making & breaking characteristics breaking capacity 400V AC-23B (A Rms)	160	256	500	800	1000	1280	1600	2520	3200	
making capacity 400V AC-23B (A Rms)	200	320	630	1000	1250	1600	2000	3150	4000	
withstand mechanical (number of operations)	10000	10000	10000	10000	10000	10000	10000	10000	10000	5000
electrical (number of operations)	3000	3000	1500	1500	1000	1000	1000	500	500	1000
operating force (mN)	2.5	2.5	7	10	10	10	10	12	15	42
connection minimum C_u cable section (mm²)	2.5	2.5	10	25	35	50	70	185	185	2x150
maximum C_u cable section (mm²)	16	16	25	95	95	95	95	240	240	2x300
fuse types	NIT20	NIT32	TIS63	TCP100	TFP125	TF160	TF200	TFK315	TMF400	TTM630

***** 630A AC22B making and breaking

switch disconnector and switch disconnector fuses

cat. ref.	description	height	width	depth
JG00S	10A TPN	136	100	74
JG01S	16A TPN	136	100	105
JG02S	25A TPN	136	100	105
JG03S	40A TPN	201	136	105
JG04S	63A TPN	201	136	118
JG05S	80A TPN	201	136	118

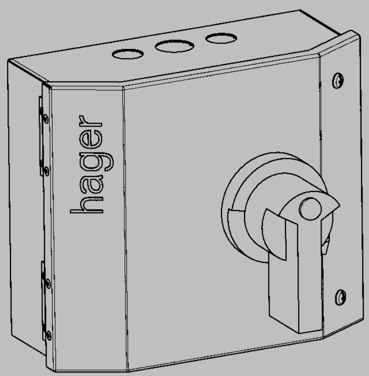
All dimensions are in mm and exclude the handle.
Add 27mm to the depth to allow for the handle on 16-25A products.
Add 32mm to the depth to allow for the handle on 40-80A products.



switch disconnectors

cat. ref.	description	height	width	depth
JG72S	20A DP	198	232	105
JG82S	32A DP	198	232	105
JG92S	63A DP	243	262	110
JG73S	20A TPN	198	232	105
JG83S	32A TPN	198	232	105
JG93S	63A TPN	243	262	110
JG52S	100A DP	348	310	122
JG62S	125A DP	348	310	122
JG53S	100A TPN	348	310	122
JG63S	125A TPN	348	310	122

All dimensions are in mm and exclude the handle.
Add 70mm to the depth to allow for the handle



switch disconnector fuses (switch fuse)

cat. ref.	description	height	width	depth
JG71F	20A SPSN	198	232	105
JG81F	32A SPSN	198	232	105
JG91F	63A SPSN	243	262	110
JG51F	100A SPSN	348	310	122
JG61F	125A SPSN	348	310	122
JG73F	20A TP&N	198	232	105
JG83F	32A TP&N	198	232	105
JG93F	63A TP&N	243	262	110
JG53F	100A TP&N	348	310	122
JG63F	125A TP&N	348	310	122

All dimensions are in mm and exclude the handle.
Add 70mm to the depth to allow for the handle

switch disconnector and switch disconnector fuses

enclosed thermal current I_{the}			20	32	63	100	125
rated insulation voltage U_i (V)			690	690	690	690	690
rated thermal current I_{the} (A)			40	63	80	100	160
rated operational current							
AC-21	400V	I_e (A)	40	63	80	100	160
AC-22	230V		25	40	63	100	125
AC-22	400V	cos phi 0.65	20	32	63	100	125
AC-23	230V		20	32	63	100	125
AC-23	400V	cos phi 0.35	15	25	40	63	80
rated operational power							
AC-23	230V	(kW)	5.5	7.5	11	15	30
AC-23	400V		11	15	22	30	37
rated fused short circuit current							
back-up fuse	(A)		63	63	80	100	160
R.M.S. value Ik	(kA)		50	50	50	50	50
peak value	(kA)		6.6	7.2	8.3	8.7	13.7
rated short circuit making capacity (I_{cm}) (kA)			6.6	7.2	8.3	8.7	13.7
rated short-time withstand current (I_{cm}) (kA)			1	1.1	1.6	1.7	2.8
rated breaking capacity I_{cn} (A) AC-23							
	400V	cos phi 0.35	270	320	480	504	840
electrical endurance (number of operations)			3000	3000	3000	3000	2000
mechanical endurance (number of operations)			50000	50000	50000	50000	16000
terminals mm²			1.5-16	1.5-16	2.5-35	2.3-35	6-70
max. thermal torque (Nm)			1.8	1.8	2.5	2.5	4.5

IP65 enclosed isolating switch

enclosed thermal current I_{the}			16	25	40	63	80/100
rated insulation voltage U_i (V)			690	690	690	690	690
rated thermal current I_{the} (A)			25	40	63	80	100
rated operational current							
AC-21	400V	I_e (A)	25	40	63	80	100
AC-22	230V		16	25	40	63	100
AC-22	400V	cos phi 0.65	16	20	32	63	100
AC-23	230V		16	20	32	63	100
AC-23	400V	cos phi 0.35	16	15	25	40	63
rated operational power							
AC-23	230V	(kW)	4	5.5	7.5	11	15
AC-23	400V		7.5	11	15	22	30
rated fused short circuit current							
back-up fuse	(A)		63	63	63	80	100
R.M.S. value Ik	(kA)		50	50	50	50	50
peak value	(kA)		5.4	6.6	7.2	8.3	8.7
rated short circuit making capacity (I_{cm}) (kA)			5.4	6.6	7.2	8.3	8.7
rated short-time withstand current (I_{cm}) (kA)			0.9	1	1.1	1.6	1.7
rated breaking capacity Icn (A) AC-23							
	400V	cos phi 0.35	250	270	320	480	504
electrical endurance (number of operations)			3000	3000	3000	3000	3000
mechanical endurance (number of operations)			50000	50000	50000	50000	50000
terminals mm²			1.5-16	1.5-16	1.5-16	2.5-35	2.3-35
max. thermal torque (Nm)			1.8	1.8	1.8	2.5	2.5