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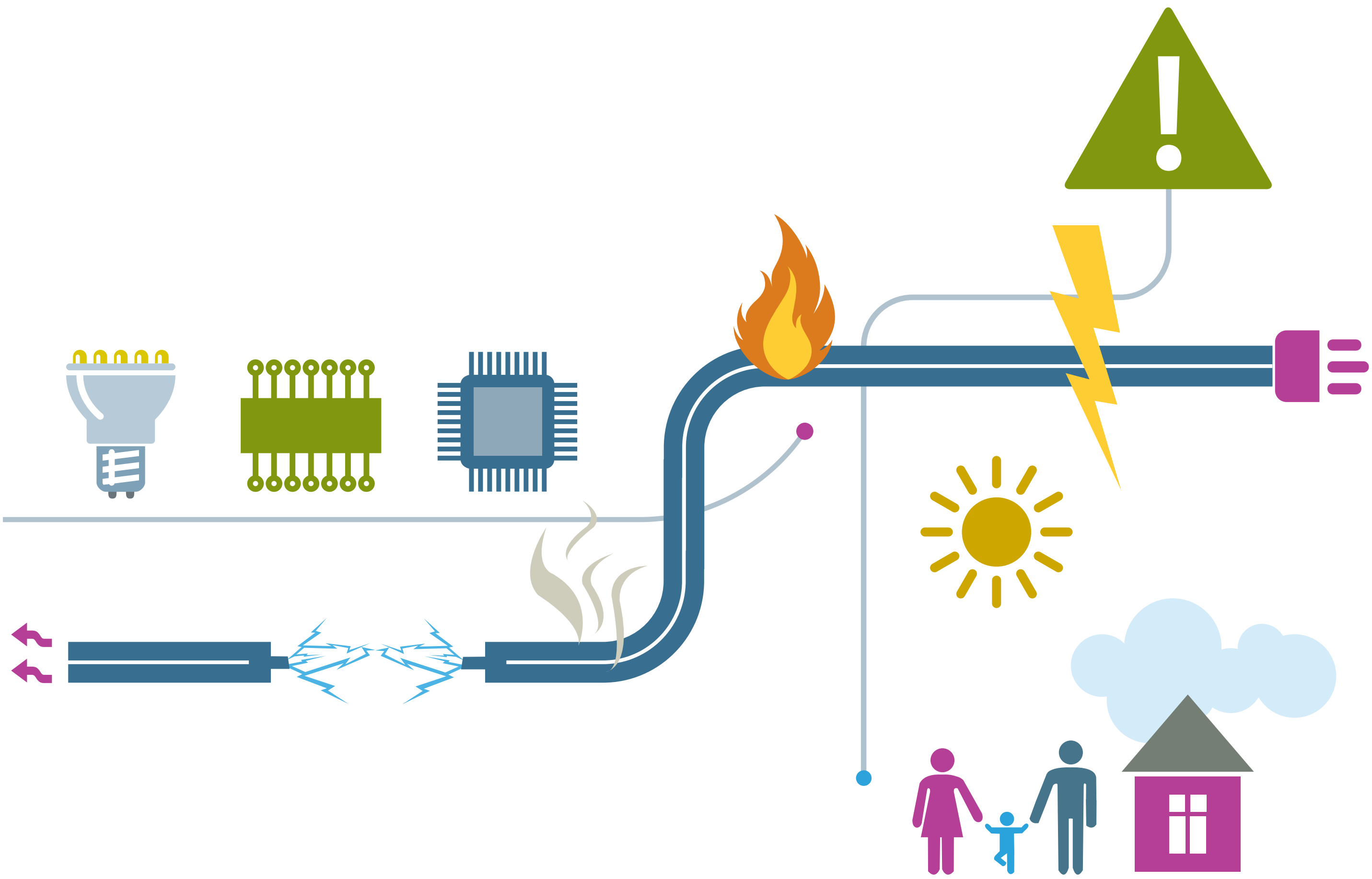
GUIDE TO CIRCUIT-BREAKER SELECTION FOR LED LIGHTING



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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 selection of circuit-breakers (MCBs, RCBOs) for supplying LED lighting circuits.

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 **www.beama.org.uk**

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The Institution of Lighting Professionals (ILP) endorses this publication.
www.theilp.org.uk

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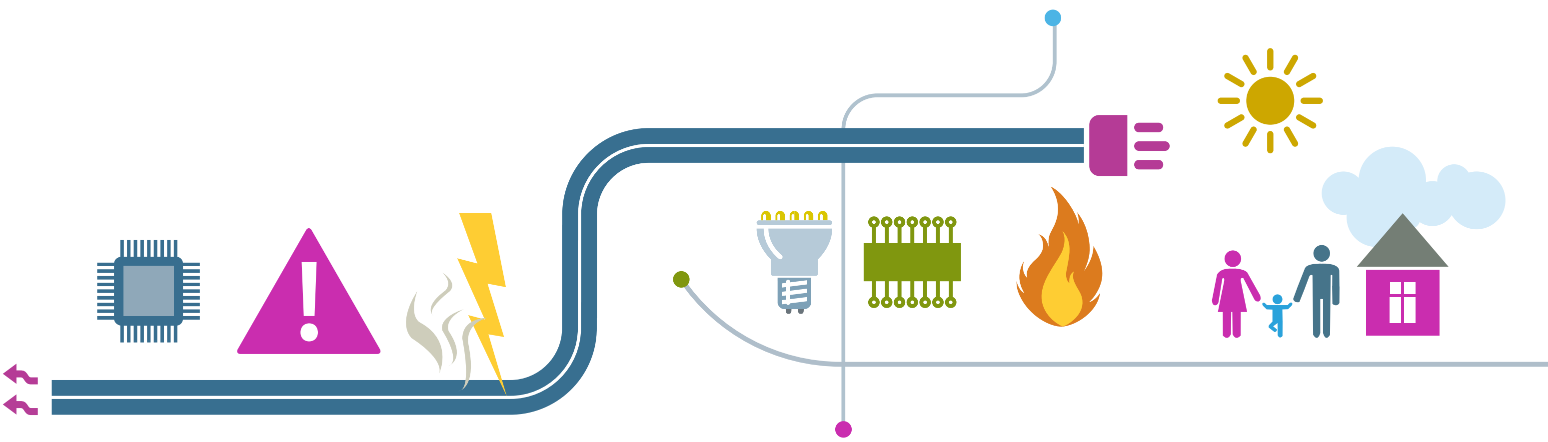


1. Scope of this guidance

Primarily, circuit-breakers are selected for overcurrent protection of the wiring system and fault / electric shock protection. In certain cases, to avoid unintentional operation, the peak current values of the loads have to be taken into consideration. This guide relates to selection of circuit-breakers when supplying LED lighting so as to avoid unintentional operation by inrush currents.

The circuit-breakers considered in this guide are those conforming with:

- BS EN 60898 series which are referred to as MCBs, and
- BS EN 61009 series which are referred to as RCBOs

2. LED lighting terminology in relation to this guide

- **LED lighting:** LED lighting system e.g. luminaire with LEDs and internal or external LED drivers and associated components.
- **Light Emitting Diode (LED):** A semiconductor which emits light when a current passes through it. LED semiconductor materials convert electrical energy into visible electromagnetic radiation (i.e., into light).
- **LED Driver:** An electronic device which converts the network alternating electricity supply (AC) to direct voltage and current appropriate for the LED luminaire. The driver may be external or internal to the luminaire and can power one or more luminaires.
- **Inrush current:** Transient current when energizing LED lighting.
- **Inrush current pulse duration:** The time duration over which the value of the inrush current is larger than 50 % of the peak inrush current as per BS EN 63129.
- **Peak inrush current:** Maximum value of inrush current which is typically reached when switch-on occurs when the mains voltage is at its peak.

The electrical circuit interfacing between the AC mains supply and the LED lamp module, termed an LED driver can cause high inrush currents to flow. The LED driver circuit can be integrated in the lamp, in a separate case built into a luminaire or external to the luminaire. The LED driver circuit characteristics affect the inrush current peak and duration, as opposed to where it is located. The term LED lighting is used in this guide regardless of where the AC supplied LED driver is located (internal or external). References to multiple LED drivers is to be interpreted as multiple lamps, luminaires, drivers or a combination of them as appropriate.

3. LED lighting inrush current

When the AC supply is switched on, LED lighting can cause an initial peak transient current several hundred times higher than their load current during normal operation; this is compounded by simultaneous switching of multiple LED lighting. This inrush current typically lasts less than 1 ms. The inrush current is caused by the charging of capacitors in the power supplies of the LED lighting or because of the initial low magnetic flux in the transformer in the power supply. The peak inrush current magnitude and inrush current pulse duration are key parameters in characterising the inrush current profile, which are important when selecting circuit-breakers so as to avoid unintentional operation.

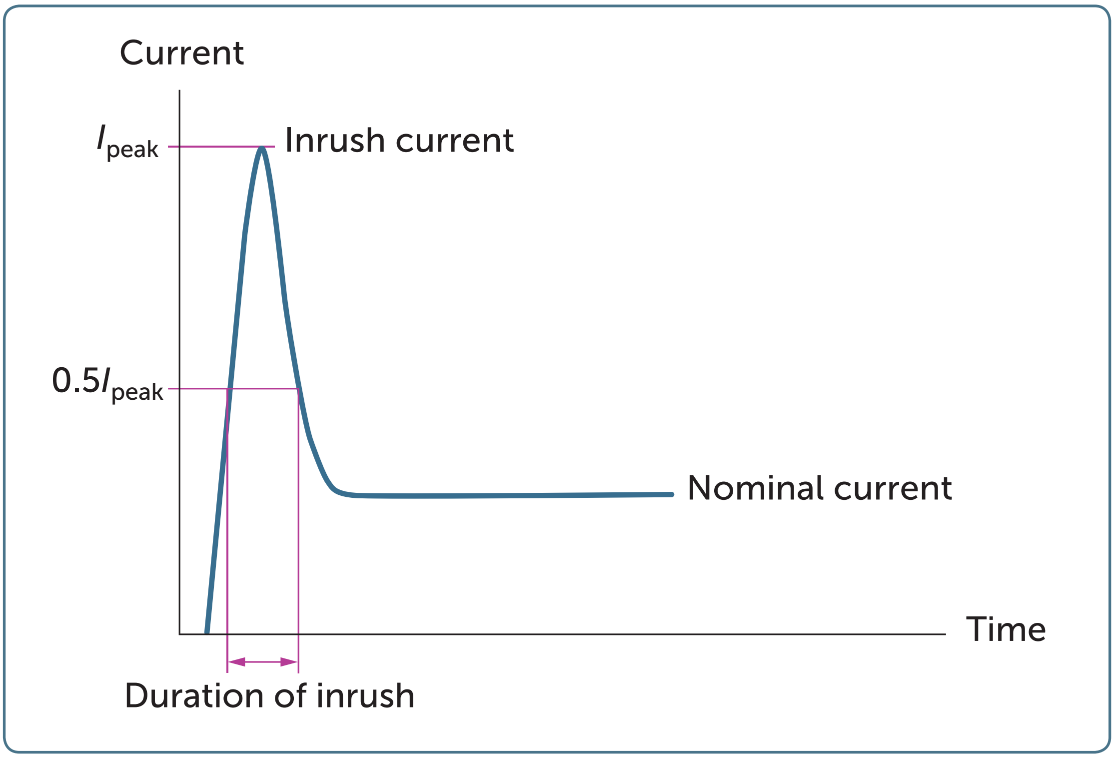


FIGURE 1 – Typical LED lighting inrush current profile

The method for determining peak inrush current characteristics for lighting products is set out in BS EN IEC 63129 (Determination of inrush current characteristics of lighting products). This standard establishes lighting products peak inrush current (I_{peak}), and peak inrush current time period (t_{H50}) at $0.5I_{peak}$.

I_{peak} and t_{H50} are used for the selection of MCBs/RCBOs for LED lighting.

LED lighting manufacturers provide peak inrush current and time duration data however it should be verified that the data is I_{peak} and t_{H50} as stipulated in BS EN IEC 63129.

4. Selection of MCBs & RCBOs for LED lighting circuits

LED lighting inrush current characteristics can vary significantly between manufacturers therefore, when selecting an MCB or RCBO:

It is critical that the MCB/RCBO manufacturer's and LED lighting manufacturer's guidance is applied. It cannot be assumed that guidance from one MCB/RCBO manufacturer can be applied to another manufacturer's MCBs/RCBOs.

Many LED lighting manufacturers provide a table detailing the number of LED drivers that can be supplied from a rating/type of MCB/RCBO but this is only to be considered as general guidance, it cannot accurately be applied to all MCB/RCBO manufacturers' products.

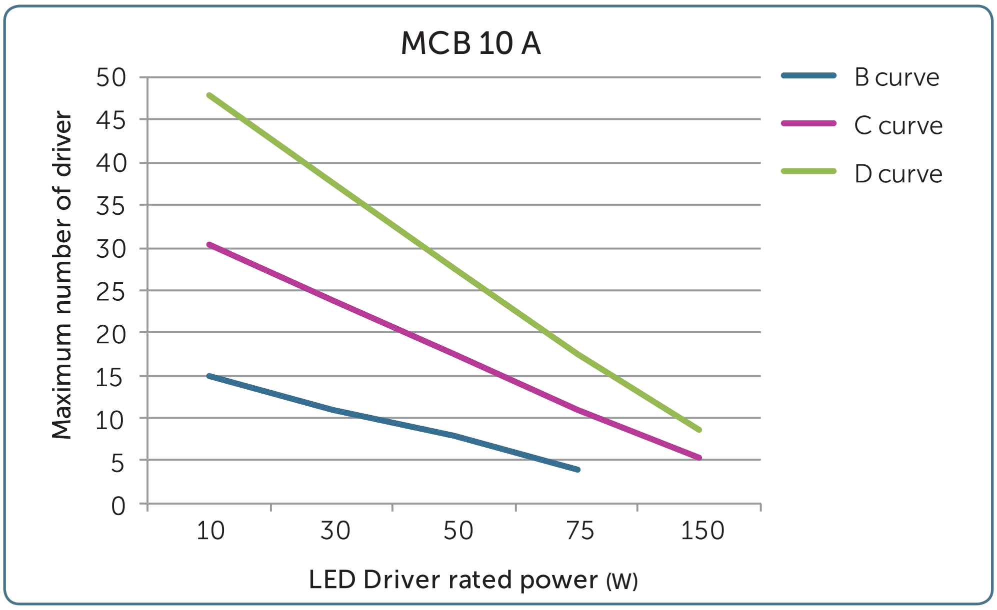
As a general principle to avoid unwanted tripping of an MCB/RCBO, the number of LED drivers supplied by an MCB/RCBO can be increased if they are not switched on simultaneously.

MCB/RCBO manufacturers use varying methods for the selection of MCBs/RCBOs for supplying LED lighting, as detailed in 4.1 to 4.4 below.

4.1. Selection using a chart based on the rated power of the LED driver(s) and the instantaneous non-tripping current of the MCB/RCBO

This method involves consideration of the power rating of the LED driver and the instantaneous tripping curves of the MCB/RCBO.

The following charts are an example of the type of information provided by an MCB/RCBO manufacturer on how many LED drivers can be supplied by the MCB/RCBO based on the MCB/RCBO Type (B, C or D).



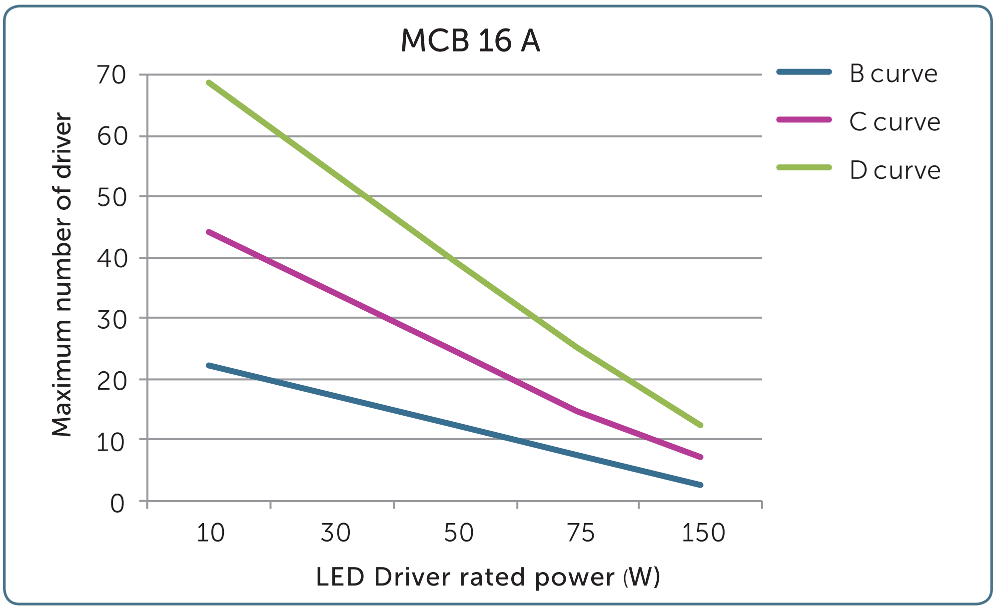


FIGURE 2 – Example charts on number of LED drivers

Note: In this manufacturer's example, for LED driver ratings lower than 10W, with respect to inrush currents causing unwanted tripping, there is no limitation on the number of drivers that can be supplied by this manufacturer's MCB/RCBO.

4.2. Selection using the LED driver(s) peak inrush current (I_{peak}) and peak inrush current time duration (t_H)

For this method, the peak inrush current (I_{peak}) of the driver is divided by the MCB/RCBO (In) rating, the result is correlated to the peak inrush current time (t_H) to select the instantaneous type of MCB/RCBO to be applied.

The example below shows a graph of the average non-tripping curve for the time range of 50 µs to 10 ms.

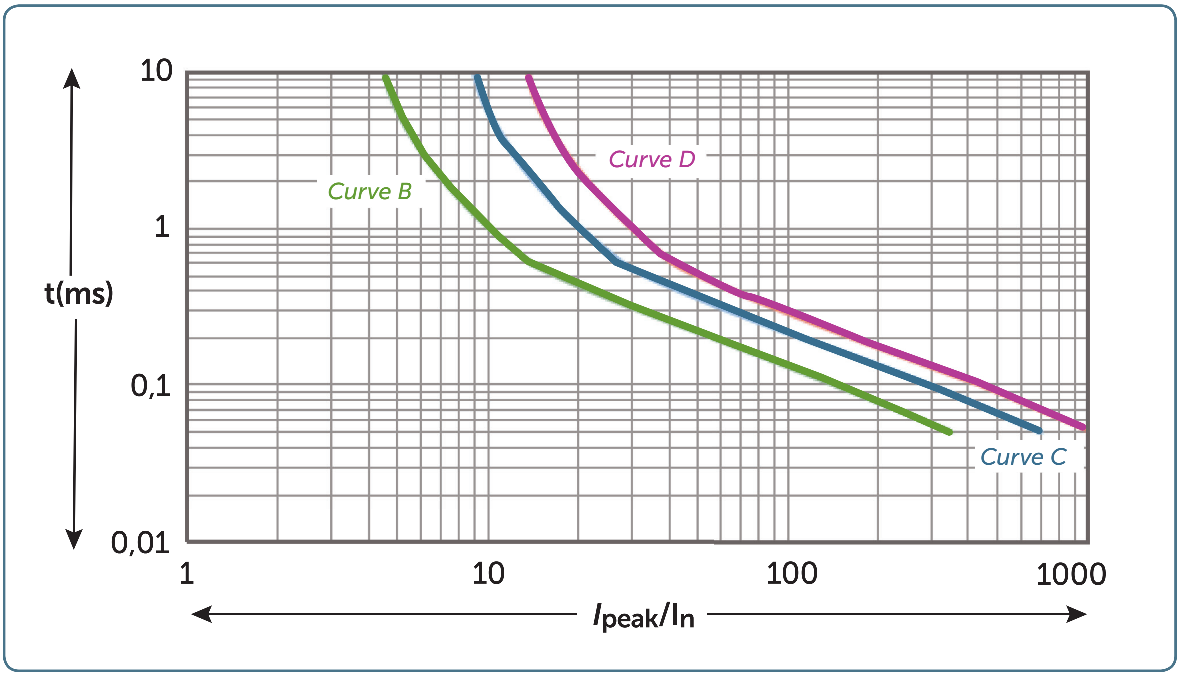


FIGURE 3 – Example graph of average non-tripping curve for time range 50 µs to 10 ms

Example

For a 10 A ((I_n) MCB/RCBO and a load of 100 A LED driver peak inrush current (I_{peak}) with a duration of 200 µs (t_{H50}):

> using the chart above, I_{peak} /I_n = 100/10 = 10 which correlates to 1 ms non-tripping time which is greater than the 200 µs peak inrush current time duration, therefore a Type B circuit breaker can be selected.

If t_{H50} > 1 ms, a Type C or Type D MCB/RCBO would need to be selected.

4.3. Selection using a 'factor' based on pulse duration

This method uses a 'factor' based on the time duration of the peak inrush current. This factor is then used to calculate the MCB/RCBO maximum non-tripping peak current for the specified time. An example is given below:

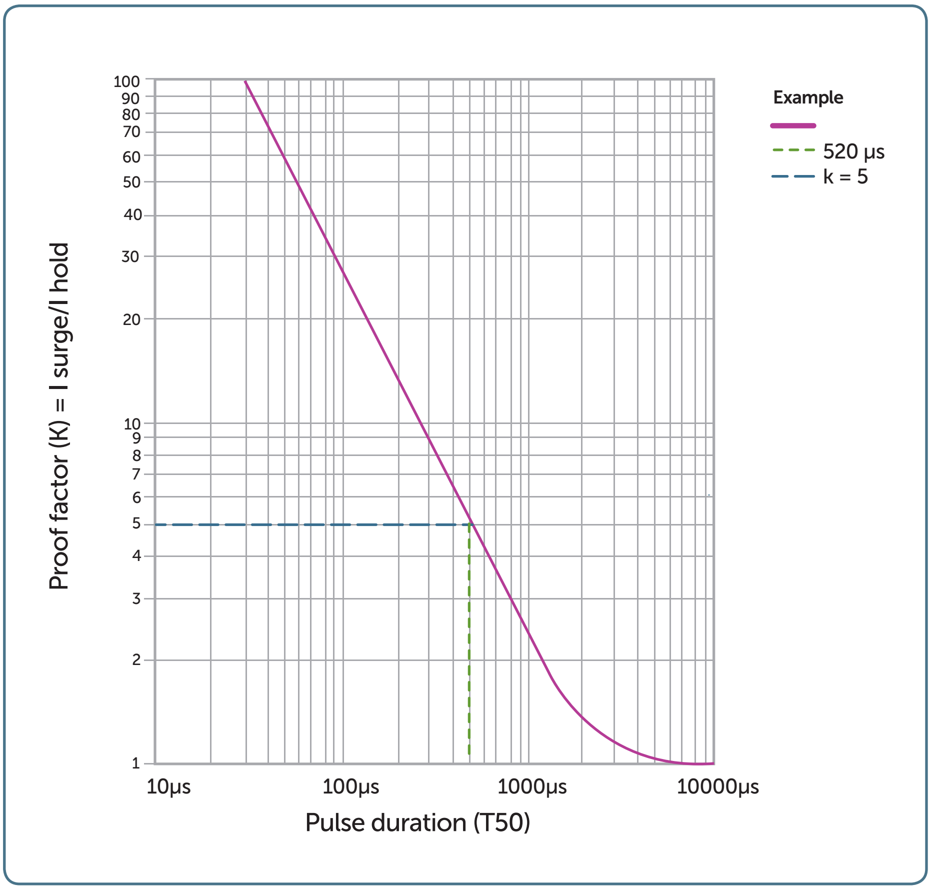


FIGURE 4 – Example graph of 'factor' based selection

No-trip peak current = factor x lower value of instantaneous current* x current rating

For example : 520 µs peak current time duration (factor 5) with B16 circuit breaker

No-trip peak current = 5 x 3 x 16 = 240 A

Therefore, for a LED driver with an inrush peak of 40A, the calculation would be:

240 / 40 = 6 drivers

** MCB/RCBO minimum instantaneous tripping current – 3 for Type B, 5 for Type C, 10 for Type D*

4.4. Selection based on MCB/RCBO peak current / time data

The MCB/RCBO manufacturer may publish non-tripping information that would enable selection of an MCB/RCBO for LED lighting e.g. “a peak current 420 A and pulse time less than 250 μs will not trip the MCB/RCBO”.

Example

LED drivers have a peak inrush of 22 A for 200 μs. How many drivers can a 10 A Type B MCB/RCBO supply, if they are switched on simultaneously?

An MCB/RCBO manufacturer states that their 10 A Type B MCB/RCBO will not trip with 420 A peak current with a duration of less than 250 μs.

Calculation: 420 A / 22 A = 19 LED drivers

Therefore, as the pulse time of 200 μs is less than the 250 μs tripping time of the MCB/RCBO, 19 LED drivers can be supplied by the MCB/RCBO.

5. Alternative solutions

5.1. Inrush limiter solutions

An inrush peak current limiter is a device that prevents inrush currents that would otherwise trip the MCB/RCBO or cause potential damage to the switching devices. Using this solution negates the need to apply selection criteria detailed in 4.1 to 4.4 above.

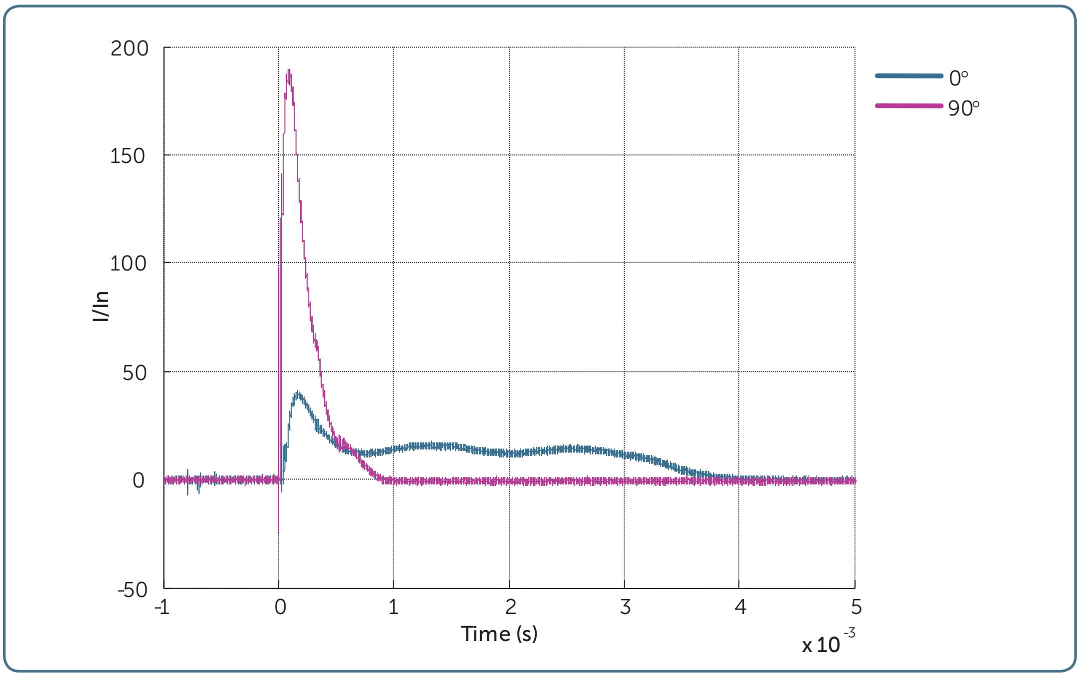


FIGURE 5 – Illustration of a peak current limiter which ensures switching on at zero crossing of the voltage wave angle and not 90°

5.2. Timed switching of LED lighting

Some manufacturers offer auxiliary devices such as time-delay modules that can be coupled to MCBs or used as stand-alone devices that can be incorporated into lighting circuits. These provide timed switching of LED lighting thus spreading the inrush currents in time, allowing more drivers to be installed on a single MCB/RCBO. Time-delay devices can also be used in conjunction with programmable logic counters (PLCs) to manage large inrush currents by co-ordinating the switching of multiple circuits in a pre-determined sequence.

5.3. Integral programable or random time delay

Some LED lighting manufacturers include an integral programable or random time delay between power on and the peak inrush current. For a group of luminaires on the same circuit, this spreads the inrush currents in time, allowing more drivers to be installed on a single MCB/RCBO. This information is made available in the lighting manufacturer's literature.

6. Other considerations for design of LED lighting circuits

6.1. LED lighting earth leakage current

RCCBs conforming to BS EN 61008 and RCBOs conforming to BS EN 61009 are residual current operated circuit-breakers. In addition to consideration of the circuit breaker element and LED driver inrush current, consideration needs to be given to LED lighting earth leakage / protective conductor current and avoiding unwanted operation.

The product standard for luminaires, BS EN 60598-1, prescribes a maximum earth leakage / protective conductor current for ratings ≤ 7 A as 3.5 mA r.m.s. per luminaire. In practice, LED lighting will produce earth leakage / protective conductor currents significantly lower than 3.5 mA. Therefore, manufacturer's data should always be consulted.

6.2. Guidance for domestic installations from Building Regulations

The domestic building services compliance guide (for use in England amended 2018) recommends that for fixed internal lighting, a single switch should normally operate no more than six light fittings with a maximum total load of 100 circuit-watts. This means that a single switch should not control more than a total of 100 circuit-watts LED lighting. This may help reduce unwanted operation of an MCB/RCBO by limiting the total number LED lights switched simultaneously.

Circuit-watt means the power consumed in lighting circuits by lamps and, where applicable, their associated control gear (including transformers and drivers) and power factor correction equipment.

6.3. Control device current ratings

Another consideration associated with LED driver inrush currents is the switch current rating, which could influence the number of LED drivers controlled together. The BEAMA guide *"Load ratings for manually operated functional switches"* provides guidance. Also, any automatic lighting controller, contactor etc should be selected based on the manufacturer's current ratings for LED lighting, this could restrict the number of LED drivers switched simultaneously and the related peak current for circuit-breaker selection.

6.4. Electrical installation design current for LED lighting

LED driver circuits range from very simple and crude circuits consisting of a few diodes, capacitors and resistors, to advanced multi-stage converters. Between these extremes lie a number of different converter circuit designs with varying degrees of efficiency and more importantly Power Factor Correction.

When establishing the electrical installation design current for LED lighting, the power factor needs to be accounted for. For example, a 100W LED luminaire with a Power Factor (Pf) of 0.85 and ignoring any inherent inefficiency of the luminaire, at full power would be using 100÷0.85=118 VA. Assuming 230 V, the design current would be: 118 VA / 230 which would be greater than using the 100 W rating of the LED luminaire.

Depending upon the type of LED lighting technology, the power factor can vary from 0.5 to 0.99, so LED lighting manufacturer's data should be used to ensure the correct VA value is used to establish the design current.

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