Thought leadership
White paper

CROUSE-HINDS SERIES

How to select the right LED luminaire and the correct number for a Miniature Circuit Breaker (MCB)

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Challenge:

LED luminaires use alternating current/direct current (AC/DC) converters to supply a regulated direct current (DC) output to the LED components in them.

Inrush current is the initial current drawn by capacitive (Electro-Magnetic Interference (EMI) filters, safety capacitors) and inductive (transformer, common mode chokes) loads of AC/DC converters. Inrush currents can be several times the magnitude of the steady state current that lasts for less than one (1) millisecond.

Though, this duration is for a very short time, some of the miniature circuit breakers (MCBs) respond to this peak current and trip the circuit leading to the shut off the LED light source without the existence of a fault condition

Solution*:

In order to ensure that the miniature circuit breaker(s) (MCBs) do not trip under this 'no fault' scenario, it is critical to pick the right type of MCBs. This selection depends on the inrush current characteristics of the control gear/driver used in the luminaire and the type, ratings of the MCB.

*The information provided here should be used as a guideline only. It is recommended that Certified Electrical engineers evaluate the installation needs, national safety standards to help make the appropriate selection of the miniature circuit breakers (MCBs).

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Understanding inrush current

When it comes to LED, there are several advantages over Inrush current is specified in-terms of its peak value and pulse width. (See figure 1 for a typical inrush current waveform) Peak values of inrush currents for the control gear/driver used in ECH LED luminaires vary in the range of several tens of amps for AC input voltages of 100 to 277VAC 50/60 Hz. The pulse width (duration of the inrush current) is defined as the time duration at 50% of the peak value of the inrush current. Typical pulse width for the control gears used in ECH LED luminaires are in the range of several hundred micro-seconds. Inrush current characteristics of LED drivers are also specified in-terms of I2t value. This is useful in selecting compatible fuses, relays, dimmers to work with multiple light fixtures. NEMA 410 standard describe the criteria that a control gear that is connected to a lighting branch circuit should meet.

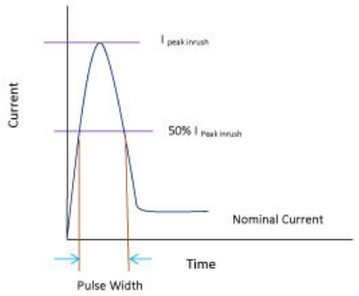

Figure 1: Inrush current waveform

The magnitude and pulse width of inrush current depends on following factors.

- **Input voltage:** peak value of the inrush current increases with input AC voltage
- **Line impedance:** peak value of the inrush current waveform helps reduce with line impedance
- **Temperature:** peak value of inrush current increase with temperature, and pulse width reduce with temperature
- **Phase angle of the AC waveform at which LED drivers are turned ON:** peak value of the inrush current waveform is highest when LED drivers are switched ON at 90 or 270 angles of an AC waveform

ANSI C82.16 -2015 describe a method to measure inrush current or model inrush current for simulation purposes for LED drivers.

In some cases, this steady state current rating of the luminaire can dictate the number of fixtures installed per breaker. Nominal or steady state current of LED luminaires are listed in the nameplate of the product.

Understanding miniature circuit breakers

Miniature circuit breakers (MCBs) are resettable protective devices against abnormal conditions in electrical circuits such as over current/load, short circuits and ground faults.

MCB type	Trip current limits
B	3 to 5 in**
C	5 to 8 in**
D	10 to 20 in.

Figure 2: Trip current limits

**In – Rated current of the breaker.

Several types of MCBs are available in the market. Selecting the right MCB depends on certification type such as UL or IEC, nominal trip/interrupt currents, AC or DC operation, input voltage range and application (such as residential, commercial or industrial).

Breakers use an alphabet code such as a B, C or D type that have different trip current characteristics for use in various applications. (Refer to figure 2)

B type circuit breakers are used in residential applications where the loads are resistive in nature.

C or D types are used in commercial/industrial applications where the loads are typically capacitive and/or inductive.

The Z, S or K type breakers are for special case use and will not be discussed here.

How to estimate the number of fixtures per miniature circuit breaker

Maximum number of fixtures that can be connected to a miniature circuit breaker (MCB) is dictated by both inrush current characteristics and nominal current rating of the luminaire.

When estimating number of fixtures to avoid trigger overload protection of the MCB, the following approach should be followed.

First, determine these critical items.

- The current rating of MCB and nominal input current rating of luminaire at required input voltage
- The de-rating factors for selected MCB based on temperature. *Current rating of a MCB is specified at a reference temperature. MCB should be de-rated for operating temperatures that are outside the reference temperature. These de-rating factors are provided by MCB manufacturers.*
- The de-rating factor when multiple MCBs are mounted adjacent to each other in a panel.

Next, the following is used to calculate the number of LED drivers required.

Maximum number of LED drivers = (MCB rated current x derating factors) / Input current of luminaire

MCB manufacturers provide trip current characteristics for their breakers (refer to a few examples below in Figure 3 and Figure 4). It is important to note that these characteristics are specific to the manufactures of the breakers and can vary for different breaker types.

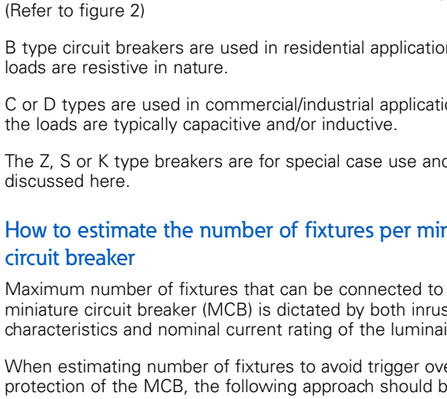

Figure 3: Tripping characteristics for Eaton xEffect FAZ series B, C & D type MCB

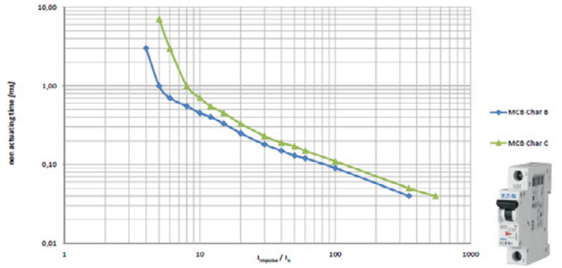

Figure 4: Eaton xEffect – B, C type FAZ series MCB trip current characteristics for low pulse duration

Next, to estimate the non-tripping current for a given MCB, evaluate the hold current (Ih). This can be calculated with equation #1 below.

Equation 1: Ih = k *c*In

Where:

- Ih is the holding current
- k is the correction factor depending on the inrush current pulse width
- c is the factor dependent on the breaker type
- In is the rated current of the breaker.

The number of fixtures that can be supported on a given breaker is calculated based on equation #2.

Equation 2: Number of fixtures = Ih / Ipeak inrush

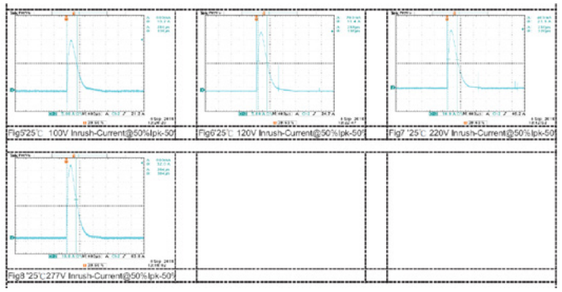

Figure 5: the Eaton's Crouse-Hinds VMVL-7 fixture /driver inrush current characteristics.

Based on data from figure 5 above, we can infer the following on the inrush current characteristics. Nominal current for these fixtures are 0.63A @120 VAC and 0.34A @ 220VAC.

AC input voltage Nominal current Peak inrush current Pulse width

AC input voltage	Nominal current	Peak inrush current	Pulse width
100	-	21.2A	336 µS
120	0.63A	24.7A	336 µS
220	0.34A	49.2A	320 µS
277	-	63.0A	304 µS

The peak inrush current increases with increasing input voltage. This is expected given the input characteristics of the control gear/driver.

For a B10A breaker with the trip current characteristics as shown in figure 4 the calculated Ih (hold current) at 120VAC can be calculated as follows.

Ih = k *c*In

Where k = 15 (from figure 4), c = 3 and In = 10A

Hence calculated Ih = 15*3*10 = 450

The number of Champ VMVL-7 fixtures that can be supported on this breaker at 120 VAC input are,

Ih / Ipeak inrush = 450/24.7 = 18.21 ~ 18 fixtures

At 220 VAC input, the number of fixtures will be = 450/49.2 = 9.14 (~ 9 fixtures)

The number of fixtures that can be supported based on nominal current calculation equals (In * 0.8)/Luminaire nominal current @ 220 VAC = 8/0.34A = 23 fixtures.

The maximum number of fixtures per MCB in this example are limited by the inrush current characteristics of the MCB.

Important considerations for miniature circuit breaker selection and size

Ambient breaker temperature

Typical load current of MCBs are provided at an ambient temperature of 30°C. (Refer to Figure 6 below for an example of derating of the load currents based on the ambient operating temperatures).

Note that several MCBs are typically mounted within a panel. Ambient temperature of each of the MCBs within a panel needs to be evaluated to determine the appropriate derating.

It is highly recommended to check the datasheet of the breaker for correction factors to be used to estimate the correct tripping values. See figure 6 on the following page.

Number of drivers per luminaire

LED light fixtures are available in various lumen/power ranges. Higher power/lumen level fixtures may use multiple drivers to power the luminaire.

While inrush current peaks of multiples LED drivers has a lower probability of coinciding with each other, it is safe to assume that is the case to avoid nuisance tripping of MCB.

In this case, the in-rush currents of individual LED drivers will be additive. It is critical that the installation designer checks for the number of drivers used in each of the luminaire to determine the total inrush current of each of the fixture.

The sum total of inrush current value must be used in the equations to estimate the number of fixtures supported per given type of MCB.

Line impedance

In a typical installation, the luminaires can be spaced far away from the breaker location and from each other. The series impedance of the power lines will be different for each of the luminaires. As impedance increases the peak value of the inrush current seen by luminaires decreases. Therefore, further a luminaire from the MCB peak value of the inrush current seen by it decreases.

Design safety factor

It is recommended to install a breaker type that has a higher nominal current rating than what is required based on the inrush calculations. This helps avoid nuisance tripping while providing the needed circuit protection.

	Ambient temperature T [°C]																
	-40	-30	-20	-10	0	10	20	30	35	40	45	50	55	60	65	70	75
I_n [A]																	
0.16	0.2	0.2	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.13
0.25	0.32	0.31	0.3	0.29	0.28	0.27	0.26	0.25	0.25	0.24	0.24	0.23	0.23	0.22	0.22	0.21	0.21
0.5	0.64	0.62	0.6	0.58	0.56	0.54	0.52	0.5	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41
0.75	0.96	0.93	0.9	0.87	0.84	0.81	0.78	0.75	0.74	0.73	0.71	0.69	0.68	0.66	0.65	0.64	0.62
1	1.3	1.2	1.2	1.2	1.1	1.1	1	1	0.99	0.97	0.95	0.93	0.9	0.89	0.87	0.85	0.83
1.5	1.9	1.9	1.8	1.7	1.7	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.2
1.6	2	2	1.9	1.9	1.8	1.7	1.7	1.6	1.6	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.3
2	2.6	2.5	2.4	2.3	2.2	2.2	2.1	2	2	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.7
2.5	3.2	3.1	3	2.9	2.8	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1
3	3.8	3.7	3.6	3.5	3.4	3.3	3.1	3	3	2.9	2.8	2.8	2.7	2.7	2.6	2.5	2.5
3.5	4.5	4.4	4.2	4.1	3.9	3.8	3.7	3.5	3.4	3.4	3.3	3.2	3.2	3.1	3	3	2.9
4	5.1	5	4.8	4.7	4.5	4.3	4.2	4	3.9	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3
5	6.4	6.2	6	5.8	5.6	5.4	5.2	5	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1
6	7.7	7.5	7.2	7	6.7	6.5	6.3	6	5.9	5.8	5.7	5.6	5.4	5.3	5.2	5.1	5
8	10.2	9.9	9.6	9.3	9	8.7	8.4	8	7.9	7.7	7.6	7.4	7.2	7.1	6.9	6.8	6.6
10	13	12	12	12	11	11	10	10	9.9	9.7	9.5	9.3	9	8.9	8.7	8.5	8.3
12	15	15	14	14	13	13	13	12	12	12	11	11	11	11	10	10	10
13	17	16	16	15	15	14	14	13	13	13	12	12	12	12	11	11	11
15	19	19	18	17	17	16	16	15	15	15	14	14	14	13	13	13	12
16	20	20	19	19	18	17	17	16	16	15	15	15	14	14	14	14	13
20	26	25	24	23	22	22	21	20	20	19	19	19	18	18	17	17	17
25	32	31	30	29	28	27	26	25	25	24	24	23	23	22	22	21	21
32	41	40	38	37	36	35	33	32	32	31	30	30	29	28	28	27	26
40	51	50	48	47	45	43	42	40	39	39	38	37	36	35	35	34	33
50	64	62	60	58	56	54	52	50	49	48	47	46	45	44	43	42	41
63	81	78	76	73	71	68	66	63	62	61	60	58	57	56	55	53	52

Figure 6: Temperature derating for Eaton xEffect FAZ series MCBs

Summary

In summary, there are several factors that can influence the tripping performance of a miniature circuit breaker (MCB). The information provided here should be used as a guideline only. It is recommended that Certified Electrical engineers evaluate the installation needs, national safety standards to help make the appropriate selection of the miniature circuit breakers (MCBs).

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