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SIBA technical background information:
Know-how on electrical fuses

Protecting energy-efficient motors

Principles for selecting aM- and gG-fuses for energy-efficient motors

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Protecting energy-efficient motors

Principles for selecting aM- and gG-fuses for energy-efficient motors

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1 Introduction

The reasons for reducing CO_2 emissions and energy consumption and for saving resources have been subject to comprehensive legislation. A major potential for saving energy lies in the electrical energy consumption of electric motors used for driving machines, as this accounts for approximately 70 % of the overall industrial energy consumption.

The energy consumption and energy efficiency, respectively, of line operated standard three-phase motors in industrial applications are covered in Regulation (EU) 640/2009 and amending Regulation (EU) 04/2014. These regulations apply in all EU countries.

International Standard IEC 60034-30-1:2014 defines the efficiencies or efficiency classes, respectively, for all relevant motors at 50 Hz and 60 Hz and lists any applicable exceptions. As of 1 January 2017, energy efficiency class IE3 is **mandatory** for line operated electric motors with a rated power output between 0.75 kW and 375 kW.

2 Efficiency classes

The efficiency of a motor is determined by the conversion of electrical into mechanical power. For three-phase motors, new efficiency classes (IE = International Efficiency Class) have been defined in accordance with IEC 60034-30-1.

IE1	Standard efficiency
IE2	High efficiency
IE3	Premium efficiency
IE4	Super Premium efficiency
IE5	New efficiency class yet to be introduced

3 Standard motors in accordance with IEC 60034-30-1

The standard IEC 60034-30-1:2014 defines five globally applicable efficiency classes for low-voltage three-phase motors with 2, 4, 6 or 8 poles having a power range from 0.12 kW to 1000 kW at a rated voltage from more than 50 V to 1 kV.

It covers not only three-phase cage-rotor induction motors, but all types of electric motors with direct on-line operation. The new efficiency class IE5 has not yet been defined in detail, but is intended to be introduced in the next edition of the standard.

4 Behaviour of high-efficiency motors

Motor manufacturers have improved and partially redesigned their products to enhance their efficiency [1]. These modifications lead to high-efficiency motors having a higher inductivity and smaller copper losses resulting in starting currents higher than those of IE1 and IE2 standard motors. Consequently, more stringent requirements apply to the switching devices such as contactors, motor protection switches and fuses.

When selecting fuses, the increased starting currents shall be taken into account.

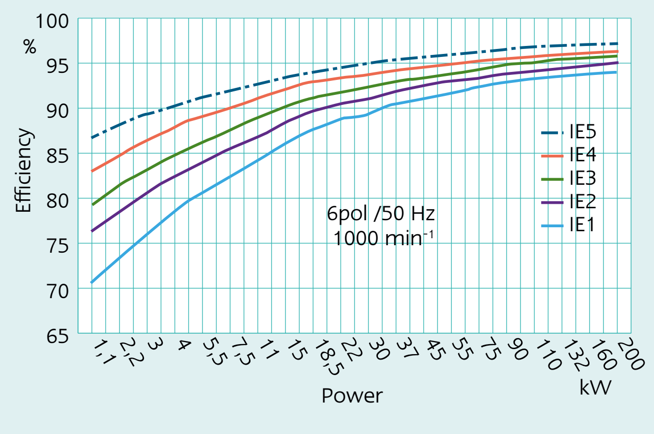

Figure 1: Starting currents

5 Modifications to IE3- and IE2-motors as compared to IE1-motors

- Rated current In reduced by an average of approximately 3 % to 5 % (more for smaller motors and less for larger motors)
- No significant change of power factor for deviations from full load
- Starting current ratio Ia/In (starting current/rated current) higher than that of IE1 motors: increase by up to 35 % for small motors (< 3 kW), by at least 3 % to 15 % for medium sized motors and by less than 7 % for motors of 75 kW and above (values taken from Figure 2)
- Run-up time slightly reduced
- Temperature rise in the steady-state operating mode reduced by approximately 10 K to 15 K [2]

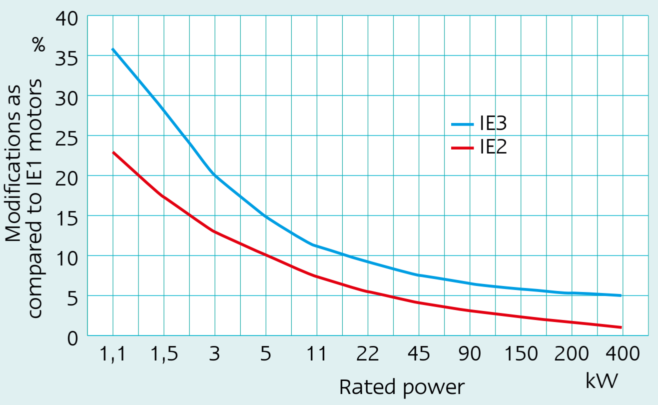

Figure 2: Change of starting current ratio

6 Consequences for electric components and fuses

The characteristic curve for aM fuses remains unchanged. Therefore, the assignment of fuses for motor protection or for switchgear shall be adapted accordingly.

Fuses can protect motors neither from excessively high starting currents nor from internal short circuits. The fuses are intended to protect the components within the motor circuit from the effects of a short circuit when it occurs.

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It is the main purpose of a fuse to enable a so-called "Back-Up Protection" of the switching device. If the short-circuit current within a motor circuit exceeds the rated breaking capacity of the motor contactor, the fuses will take over the switching task, provided they have been dimensioned correctly. For this purpose, it is essential that the fuses break the circuit before contactor contacts welding occurs.

Principally, potential overload currents shall be switched off by other suitable protection means.

7 Definition of rated current for aM and gG fuses:

Determine or calculate the rated current of the motor:

$$I_{n\,(Motor)} = P_n / (\cos\varphi * \eta * U_n * \sqrt{3})$$

Calculate the minimum rated current of the fuse:

$$I_{n\,min\,(Fuse)} \geq I_{n\,(Motor)}$$

For ambient temperatures higher than 20 °C, derating factor K_{th} is taken into account in the calculation.

$$I_{n\,min\,(Fuse)} \geq I_{n\,(Motor)} / K_{TH}$$

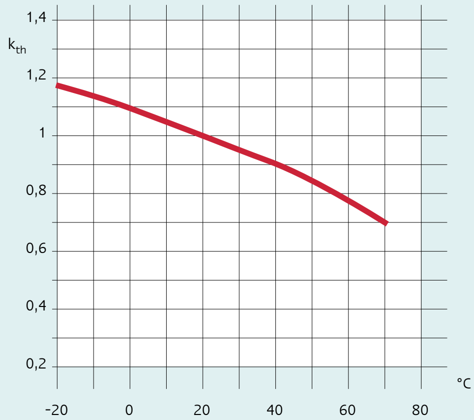


Figure 3: Selection of rated current as a function of ambient temperature

8 Checking the characteristic curve of a selected fuse

The starting current of the motor shall not cause damage of the fuse at the end of the run-up time. The selectivity coefficient B2 = 0.6 (applicable to SIBA aM <0,8 and gG <0,7) is used to check whether the starting current (I_{START}) of the motor and the point (I_{TCC}) on the time/current characteristic of the fuse are at an appropriate distance to each other.

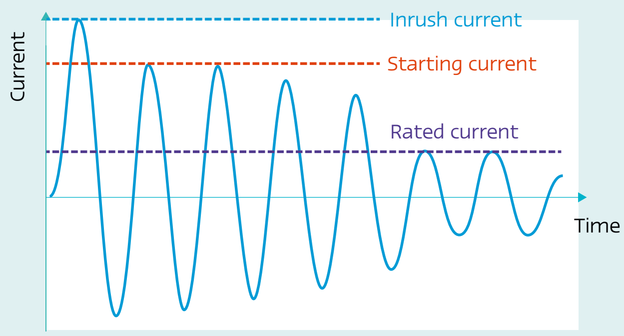


Figure 4: Starting current

9 Examples

The rated motor current of an IE3-motor (55 kW, 4-pole, 400 V) is 96 A, its run-up time is 5 seconds and the starting current of the motor is equal to 8 times its rated current.

Check whether the current lies within the safe distance (I_{START}/B2) on or left of the point (I_{TCC}) of the characteristic curve of the fuse.
Afterwards, check whether the overall integral of the fuse is smaller than the I^2t-value of the switchgear; then the suitable fuse has been selected

Example 1

Selectivity coefficient B2 = 0,8
I_{START} = 8 * 96 A = 768 A

I_{START} / B2 ≤ I_{TCC}

768 A / 0,8 = 960 A ≤ I_{TCC} (1170 A)

Fuse selection:

160 A, aM,
Art.-Nr.: 20 211 08.160

Example 2

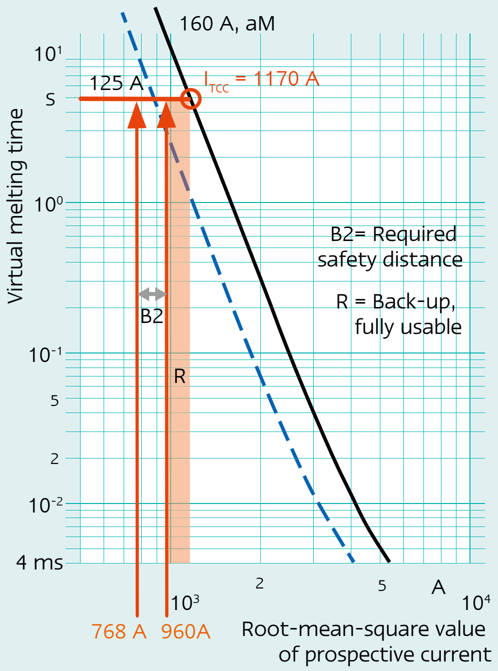
Alternative selection of fuse (gG),
Selectivity coefficient B2 = 0,7
I_{START} = 8 * 96 A = 768 A

I_{START} / B2 ≤ I_{TCC}

768 A / 0,7 = 1097 A ≤ I_{TCC} (1430 A)

Fuse selection:

250 A, gG,
Art.Nr.: 20 003 13.250



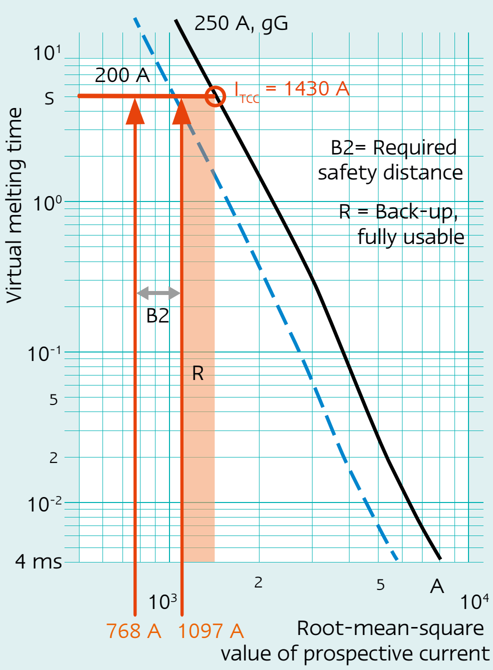


Figure 5: Examples of fuse selection

10 Protection by means of aM fuses

PN	IE2 Motors								IE3 Motors							
	U_N = 400 V Starting current I_A / 5 sec. = Run-up time				U_N = 690 V Starting current I_A / 5 sec. = Run-up time				U_N = 400 V Starting current I_A / 5 sec. = Run-up time				UU_N= 690 V Starting current I_A / 5 sec. = Run-up time			
	I_N Motor	6 x I_N	8 x I_N	10 x I_N	I_N Motor	6 x I_N	8 x I_N	10 x I_N	I_N Motor	6 x I_N	8 x I_N	10 x I_N	I_N Motor	6 x I_N	8 x I_N	10 x I_N
kW	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1,1	2	4	4	6	1	4	4	4	2	4	4	4	1	4	4	4
1,5	3	4	6	6	2	4	4	4	3	4	4	6	2	4	4	4
2,2	4	6	10	16	2	4	4	6	4	6	6	10	2	4	6	6
3	6	10	16	16	3	4	6	10	6	10	16	16	3	6	6	6
4	8	16	16	20	5	6	10	16	7	10	16	16	4	6	10	10
5,5	11	16	20	20	6	10	16	16	10	16	20	20	6	10	16	16
7,5	15	20	25	25	8	16	16	20	14	20	25	25	8	16	20	20
11	20	25	32	35	12	16	20	25	19	25	25	35	12	16	20	25
15	26	25	40	50	15	20	25	25	25	25	35	50	15	20	25	25
18,5	32	35	50	63	19	20	25	35	31	35	50	63	18	20	25	32
22	38	40	63	63	22	25	32	40	36	40	50	63	22	25	32	40
30	52	63	80	100	30	35	50	63	50	50	80	100	29	32	40	50
37	65	63	100	125	37	40	50	63	61	63	100	125	36	40	50	63
45	79	80	125	160	46	50	63	80	74	80	125	160	44	50	63	80
55	96	125	160	200	56	63	80	100	91	100	160	200	54	63	80	100
75	131	160	200	250	76	80	125	160	124	160	200	250	73	80	125	160
90	157	200	250	300	91	100	160	200	149	160	224	250	88	100	125	160
110	186	200	250	300	108	125	160	200	178	200	250	300	103	125	160	200
132	223	250	315	355	129	160	200	250	214	250	300	355	124	160	200	224
160	270	315	355	500	157	200	224	300	259	300	355	500	150	200	250	250
200	338	355	500	630	196	200	300	315	324	355	500	630	188	200	250	315
250	423	500	630	800	245	250	315	400	405	400	630	800	235	250	315	355
315	532	630	800	---	309	300	400	630	510	630	800	---	296	315	400	500
355	600	630	---	---	348	400	500	630	575	630	800	---	333	355	500	630
400	676	800	---	---	392	400	630	800	647	---	---	---	375	355	500	630

Example 1, calculation see page 5

Assumption		Assumption cos φ	Assumption		Assumption cos φ
P < 10 kW	η = 0,85	cos φ = 0,87	P < 100 kW	η = 0,88	cos φ = 0,89
10kW < P < 100kW	η = 0,92	cos φ = 0,87	10kW < P < 100kW	η = 0,94	cos φ = 0,89
P > 100 kW	η = 0,95	cos φ = 0,90	P > 100 kW	η = 0,96	cos φ = 0,93

12 Sources

[1] DIN EN 60034-30-1 (VDE 0530-30-1)

[2] New IE2/IE3/IE4 energy-saving motors – influence on coordination, Volker Seefeld, Siemens

11 Protection by means of gG fuses

PN	IE2 Motors								IE3 Motors							
	U_N = 400 V Starting current I_A / 5 sec. = Run-up time				U_N = 690 V Starting current I_A / 5 sec. = Run-up time				U_N = 400 V Starting current I_A / 5 sec. = Run-up time				UU$_N$= 690 V Starting current I_A / 5 sec. = Run-up time			
	I_N Motor	6 x I_N	8 x I_N	10 x I_N	I_N Motor	6 x I_N	8 x I_N	10 x I_N	I_N Motor	6 x I_N	8 x I_N	10 x I_N	I_N Motor	6 x I_N	8 x I_N	10 x I_N
kW	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1,1	2	6	10	10	1	6	6	6	2	6	10	10	1	6	6	6
1,5	3	10	10	16	2	6	10	10	3	10	10	16	2	6	6	10
2,2	4	16	16	20	2	10	10	16	4	16	16	20	2	10	10	16
3	6	16	20	25	3	10	16	20	6	16	20	25	3	10	16	20
4	8	20	32	40	5	16	20	20	7	20	25	35	4	16	20	20
5,5	11	32	40	50	6	20	25	32	10	32	40	50	6	20	25	25
7,5	15	40	50	63	8	25	32	40	14	40	50	63	8	25	32	35
11	20	50	63	80	12	32	40	50	19	50	63	80	12	32	40	50
15	26	63	80	100	15	40	50	63	25	63	80	100	15	40	50	63
18,5	32	80	100	125	19	50	63	80	31	80	100	100	18	50	63	80
22	38	100	100	125	22	63	80	80	36	80	100	125	22	63	63	80
30	52	100	160	160	30	80	100	100	50	100	125	160	29	63	100	100
37	65	125	160	200	37	80	100	125	61	125	160	200	36	80	100	125
45	79	160	200	224	46	100	125	160	74	160	200	224	44	100	125	160
55	96	200	250	250	56	125	160	160	91	160	224	250	54	125	160	160
75	131	224	315	355	76	160	200	224	124	224	315	355	73	160	200	224
90	157	250	355	400	91	160	224	250	149	250	315	400	88	160	200	250
110	186	315	400	500	108	200	250	315	178	315	355	500	103	200	250	315
132	223	355	500	630	129	250	315	355	214	355	400	500	124	224	250	355
160	270	400	630	630	157	250	355	400	259	400	500	630	150	250	315	400
200	338	500	630	800	196	315	400	500	324	500	630	800	188	315	355	500
250	423	630	800	---	245	355	500	630	405	630	800	---	235	355	500	630
315	532	800	---	---	309	500	630	---	510	800	---	---	296	500	630	---
355	600	800	---	---	348	500	630	---	575	800	---	---	333	500	630	---
400	676	---	---	---	392	630	---	---	647	800	---	---	375	630	---	---

Example 2, calculation see page 5

Assumption		Assumption cos φ	Assumption		Assumption cos φ
P < 10 kW	η = 0,85	cos φ = 0,87	P < 100 kW	η = 0,88	cos φ = 0,89
10kW < P < 100kW	η = 0,92	cos φ = 0,87	10kW < P < 100kW	η = 0,94	cos φ = 0,89
P > 100 kW	η = 0,95	cos φ = 0,90	P > 100 kW	η = 0,96	cos φ = 0,93

Disclaimer:

The fuses described herein have been developed to be used as components with safety-related functions in machines or complete installations. A safety-related system generally comprises signalling devices, sensors, processing units and means for safe disconnection. The manufacturer of the installation or machine is responsible for ensuring its correct overall function. SIBA GmbH and its sales offices (hereafter referred to as „SIBA“) cannot guarantee every property of a complete installation or machine not designed by SIBA. After selecting a product, the user should test this product in each intended application. SIBA will also not accept any liability for recommendations given or implied in above descriptions. Beyond SIBA's general delivery terms, no warranty, guarantee or liability claims may be derived from above descriptions.

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