

Safety characteristics

B10 values / failure rates of electromechanical SIRIUS / SENTRON products

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1 Safety characteristics of electromechanical products

1.1 Introduction

Safety characteristics In the following standards, the so-called B10 values for calculating the safety integrity or safety integrity level (SIL) in functional safety at a high or continuous demand rate are required also for electromechanical switchgear:

- IEC 62061 "Safety of machines – Functional safety of safetyrelated electrical, electronic and programmable electronic control systems"
- ISO 13849-1 "Safety of machines – Safety-related components of controls – Part 1: General principles ".

Failure rates of electromechanical components are required for calculating the safety integrity or safety integrity level (SIL) in functional safety:

- in the manufacturing industry at a high demand rate
- in the process industry at a low demand rate

Further requirements are laid down in IEC 61511-1 "Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements".

The German versions of the above standards are:

- EN 62061
- EN ISO 13849
- EN 61511-1

The TÜV-tested Safety Evaluation Tool assists in calculating the safety function as verification for the machine documentation. It is available on the Internet at www.siemens.com/safety-evaluation-tool.

At www.siemens.com/safety-integrated you will also find examples of functions with calculations according to the current standards.

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1.2 Definitions

λ (t) dt is the probability that a unit which has not failed by a certain time t will fail in the following interval (t; t +dt).

Failure rates have the dimension 1/time unit, e.g. 1/h.

Failure rates for components are often specified in FIT (failures in time unit): 1 FIT equals 10-9/h.

From the failure rate it is possible to derive a (mathematical) distribution function of the failure probability:

F(t) = 1 - exp(-λt), with λ as constant failure rate

- The mean value of this exponential distribution is also referred to as:
  - Mean Time To Failure (MTTF) in the case of irreparable components; 63.2 % of components fail by the MTTF;
  - Mean Operating Time Between Failures (MTBF) in the case of reparable components.
- MTTF = 1/λ (MTTF is a statistical mean value but no guarantee for endurance)

Electromechanical components are often irreparable components. In general, the failure rate of monitored units changes with age.

The B10 value for devices subject to wear is expressed in number of operating cycles:

- it is the number of operating cycles after which 10 % of the test specimens fail in the course of an endurance test (or: the number of operating cycles after which 10 % of the devices have failed).

For low demand rates (mainly in the process industry), the failure rate and not the B10 value is used to determine the failure probability.

The failure rate of the dangerous failures λD of the components used is needed for further calculations. Listed in the following table are the standard B10 values and the share of dangerous failures for SIRIUS product groups at a high demand rate.

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1.3 B10 values at a high demand rate

With the help of the B10 value and a simplified formula (see section 6.7.8.2.1 of EN 62061), the user can then calculate the total failure rate of an electromechanical component:

$\lambda = 0{,}1 \times C / B10$

with C = operating cycles per hour. C is specified by the user.
The failure rate is made up of safe (λS) and dangerous (λD) failures:

$\lambda = \lambda_S + \lambda_D$

or

λ_D = [share of dangerous failures in %] x λ

λ_S = [share of safe failures in in %] x λ

The failure rate of the dangerous failures λD of the components used is needed for further calculations. Listed in the following table are the standard B10 values and the share of dangerous failures for SIRIUS/SENTRON product groups at a high demand rate. (As of 2025-02, pages from SN 31920). The actual valid data can be found in the data sheets of the product itself.

The B10d value used in EN ISO 13849-1:2008 is determined as follows:

$$B10_D = \frac{B10}{\text{Share of dangerous failures}}$$

Calculation example

A protective door is monitored by a position switch with a separate actuator. The protective door is opened 4 times an hour. The overall failure rate of the position switch is:

$\lambda = 0{,}1 \cdot C / B10$ [failures/h]

$\lambda = 0{,}1 \cdot 4 / 1000000 = 4 \cdot 10^{-7}$ [failures/h]

The dangerous failure rate is calculated with

λ_D = 20 % of $\lambda = 0{,}2 \cdot 4 \cdot 10^{-7}$ [failures/h]

$\lambda_D = 8 \cdot 10^{-8}$ [failures/h]

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Table 1 Standard B10 values - 02/2025

Product group (electromechanical components)	Standard B10 value[1)] (operating cycles)	Share of dangerous failures
3SU1		
• EMERGENCY OFF/ EMERGENCY STOP control devices (with positive-opening contacts)	100 000	20 %
• Switch		
- 3 positions	300 000	20 %[6)]
- 2 positions momentary	500 000	20 %[6)]
- 2 positions maintained	100 000	20 %[6)]
• Key switch (Siemens C)		
- momentary [12)]	500 000	20 %[6)]
- 3 positions maintained [12)]	300 000	20 %[6)]
- 2 positions maintained [12)]	100 000	20 %[6)]
• Pushbuttons (momentary)	10 000 000	20 %[6)]
• Illuminated Pushbuttons (momentary)	3 000 000	20 %[6)]
3SB2/3SF5		
EMERGENCY OFF/ EMERGENCY STOP control devices		
(with positive-opening contacts)		
• Turn-to-release (and key release)	100 000	20 %
• Pull-to-release	30 000	20 %
• Key-to-release	30 000	20 %
Cable-operated switches		
3SE7 for EMERGENCY OFF/EMERGENCY STOP	100 000	50 %
(with positive-opening contacts)		
Position switch 3SE5/3SF1		
(with positive-opening contacts)		
• Standard position switches (only basic switch)	10 000 000	20 %
• Standard position switches (incl. actuator head)	1 000 000[2)]	20 %
• with seperate actuator	1 000 000	20 %
• with tumbler (spring interlocking)	1 000 000	20 %
• with tumbler (solenoid interlocking)	1 000 000	50 %

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Product group (electromechanical components)	Standard B10 value[1)] (operating cycles)	Share of dangerous failures
Foot switches 3SE29		
• momentary contact	1 000 000	50 %
• latching	100 000	50 %
Contact free Safety position switch 3SE66/3SE67	12 500 000[9)]	50 %
Contactors/motor starters for switching Motors		
• 3RT10/3RT20/3RT50/3RT60/3TF6	1 000 000[3)]	73 %
• 3RT202	1 000 000[3)]	73 %
• 3TC	1 000 000[4)]	73 %
• 3TF2	400 000[3)]	73 %
• 3TG10	400 000[3)]	73 %
Contactor relays and auxiliary switches 3RH1/3RH2/3RH6 (with positively driven contacts)	1 000 000[5)]	73 %
Circuit breaker 3RV up to 100 A [8)]	5 000[7)]	50 %
Combination Starters/ Fuseless Combination Starters 3RA1, 3RA2	1 000 000[3)]	73 %
Compact Starters		
• 3RA61		
-12 A: AC-3	3 000 000	50 %
-32 A: AC-3	2 000 000	50 %
• 3RA62		
-12 A: AC-3	3 000 000	50 %
-32 A: AC-3	2 000 000	50 %
• 3RA64		
-12 A: AC-3	3 000 000	50 %
-32 A: AC-3	2 000 000	50 %
• 3RA65		
-12 A: AC-3	1 500 000	50 %

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Product group (electromechanical components)	Standard B10 value[1)] (operating cycles)	Share of dangerous failures
-32 A: AC-3	1 500 000	50 %
SENTRON Molded Case Circuit Breakers (MCCB) Circuit Breakers 3VA up to 1250 A with undervoltage release [10)]		100%
• 3VA10/11/12 up to 100/160/250 A	7 000	
• 3VA13 up to 400 A	6 000	
• 3VA14 up to 630 A	4 000	
• 3VA15 up to 1000 A	4 600	
• 3VA20/21 up to 100/160 A	7 000	
• 3VA22 up to 250 A	7 000	
• 3VA23 up to 400 A	6 000	
• 3VA24 up to 630 A	5 000	
• 3VA25/26 up to 1000/1250 A	4 600	
• 3VA27 up to 1600 A	10 000	
• 3VA51/52 up to 125/250 A	7 000	
• 3VA53/54 up to 400/600 A	6 000	
• 3VA55 up to 800 A	4 800	
• 3VA57/58 up to 1200/1600 A	1 500	
• 3VA59 up to 2000 A	500	
• 3VA61/62 up to 150/250 A	7 000	
• 3VA63 up to 400 A	6 000	
• 3VA64 up to 600 A	4 000	
• 3VA65/66 up to 800/1000 A	4 900	
• 3VA67/68 up to 1200/1600 A	1 500	
• 3VA69 up to 2000 A	500	
SENTRON 3WA air circuit breakers [11)]		50 %
3WA frame size I		
interrupting capacity classes N and S	30 000	
interrupting capacity classes M, H and E	20 000	
3WA frame size II		
interrupting capacity classes S, M, H, E	20 000	
interrupting capacity class C	10 000	
3WA frame size III		
interrupting capacity class H	15 000	
interrupting capacity classes C and E	10 000	

[1)] Only applies under the conditions specified in the technical specifications.

[2)] The B10 value can be higher depending on the actuator head used.

[3)] The B10 value was calculated for 66 % of the rated current value Ie and AC-3/400 V. Further values on request.

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[4)] Conditions on request.

[5)] The B10 value was calculated for 30 % of the rated current value Ie for AC-15/-14/230 V or 10% of the rated current value Ie for DC-13/24 V. Further values on request.

[6)] Ratio of dangerous failure: 50% at usage of the NO contact (one positively driven contact shall be used additionally at least in a redundant architecture ; the single use of a NO contact is not allowed)

[7)] available for all sizes and attend to IEC 60947-2, IEC 60947-4-1

[8)] required is: the protection equipment is integrated via an undervoltage release in the safety function and only one high energy switch off is allowed

[9)] Valid for contact blocks w/o LED up to max. 20% of the rated current, for contact blocks with LED up to 100% of the rated current.

[10)] The B10 values for Molded Case Circuit Breakers are only valid on the following conditions:

- The circuit breaker are embedded with a UVR (undervoltage release) in a safety function (closed-circuit principle).
- The technical data of the circuit breakers according to IEC 60947-2 are met and the circuit breakers work in an undisturbed mode (e.g. no high energy switching off)
- The circuit breakers are derated, according to ISO 13849-2:2012, D.1, Table D.2, table line "oversizing”, and IEC 62061:2005, 6.7.9.2.2, note 1 and 2, so that the electrical current, which is conducted through the main switching contacts, is less than a half of the rated current In.
- Ue is max. 415 VAC

[11)] With maintenance regarding to operating manual

[12)] Key selector switch with Siemens C lock without key monitoring and locking systems (-Z Y03)

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1.4 Standard failure rates (at a low demand rate)

On the basis of the failure rates, it is possible to calculate the average probability of failure on demand (PFDavg) of a PLT protective device.

A so-called low demand rate is assumed, meaning the rate of demand on the safety-related system amounts to no more than once a year and is not greater than double the frequency of the repeat test.

A repeat test once a year is recommended for electromechanical components in order to reveal passive faults. For special applications it is possible, in agreement with the inspecting institution (e.g. a technical inspectorate, government agency or the like) to extend the test intervals by using suitable solutions (e.g. a multi-channel version etc.).

Listed in the following table are the standard failure rates and the share of dangerous failures for SIRIUS/SENTRON product groups at a low demand rate. (As of 2025-02, pages from SN 31920). The actual valid data can be found in the data sheets of the product itself.

Table 2 Normal failure rate - 02/2025

Product group (electromechanical components)	Normal failure rate (in FIT) [1]	Ratio of dangerous failures
3SU1		
• EMERGENCY OFF/ EMERGENCY STOP control devices (with positive-opening contacts)	100[6]	20 %
• Switch		
- 3 positions	100	20 %[2]
- 2 positions momentary	100	20 %[2]
- 2 positions maintained	100	20 %[2]
• Key switch (Siemens C)		
- momentary	100	20 %[2]
- 3 positions maintained	100	20 %[2]
- 2 positions maintained	100	20 %[2]
• Pushbuttons (momentary)	100	20 %[2]
• Illuminated Pushbuttons (momentary	100	20 %[2]
3SB2/3SF5		
EMERGENCY OFF/EMERGENCY STOP control devices		
(with positive-opening contacts)		
• Turn-to-release (and key release)	100[6]	20 %
• Pull-to-release	100[6]	20 %
• Key-to-release	100[6]	20 %

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Product group (electromechanical components)	Normal failure rate (in FIT) [1]	Ratio of dangerous failures
Cable-operated switches 3SE7 EMERGENCY OFF/EMERGENCY STOP (with positive-opening contacts)	100[6]	50 %
Position switch 3SE5/3SF1 (with positive-opening contacts) • Standard position switches (only basic switch) • Standard position switches (incl. actuator head) • with separate actuator • with tumbler (spring interlocking)	 100 100 100 100	 20 % 20 % 20 % 20 %
Foot switches 3SE29 • momentary contact • latching	 100 100	 50 % 50 %
Contactors/motor starters for switching Motors (with positively driven contacts or mirror contacts)	100	<40 %[4]
Circuit breaker 3RV	50	<40 %
Circuit breaker 3VA1	30[7]	100 %
Circuit breaker 3VA2	3500	100 %
Thermal overload relays	50	<40 %
Compact Starters 3RA6	100 [5]	<40 % [5]

[1] The failure rate data in the table is limited to 100 FIT (except circuit breakers and thermal overload relays)

[2] Ratio of dangerous failure: 50% at usage of the NO contact

[3] Valid under the above-mentioned conditions.

[4] The SIL level can be improved by means of fault detection using positively driven auxiliary switches

[5] Temporary value

[6] Also limited to 100 FIT due to protection against tampering together with latching

[7] The value applies for use at Ue = 415 V. At Ue = 690 V, the FIT value = 150.

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