Contact reliability

White Paper

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Executive summary

Today's industrial process equipment is increasingly automated and energy-efficient. Schneider Electric's auxiliary contacts, used in a variety of signal-processing relay devices (contactors, switches, PLCs, and circuit breakers) present in industrial process equipment offer exceptionally high reliability. This is due to Schneider Electric's broad, deep knowledge of design, materials, production engineering, manufacturing, and testing, all of which contribute to contact reliability. This document reviews the factors that influence contact reliability and demonstrates how Schneider Electric combines a patented contactor design, mastery of production engineering and manufacturing processes, and extensive factory testing to deliver highly reliable contacts.

Introduction

Low-voltage contact reliability—which concerns signal-processing relay devices like contactors, switches, PLCs, and circuit breakers—is affected by choices made at the design, manufacturing, and testing stages. Schneider Electric's in-depth knowledge of each of these stages and patented contactor design guarantees high-reliability auxiliary contactors. This document addresses Schneider Electric's theoretical knowledge of contact reliability and the testing processes used to ensure the reliability of Schneider Electric contactors. Proprietary Schneider Electric industrial engineering and manufacturing processes will not be addressed.

Definitions

Contact reliability

The probability that a contact can fulfil its required function in a given set of conditions for a given number of cycles (IEC 60947-4-5).

Contact resistance

Stability of electrical resistance at the product terminals.

These two concepts are related: Poor contact resistance increases the probability of poor contact reliability.

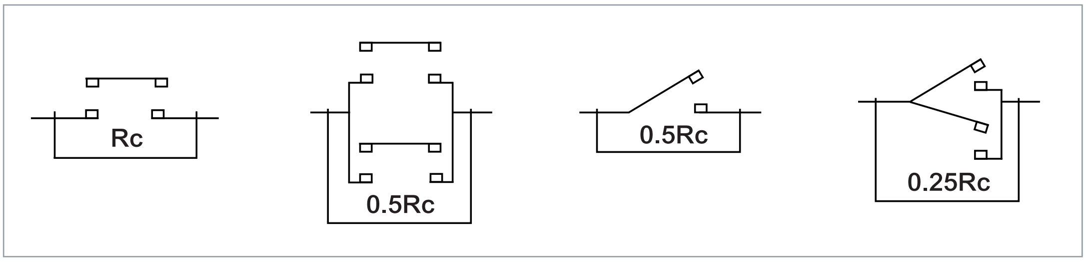
1. Influencing factors

1.1. Design

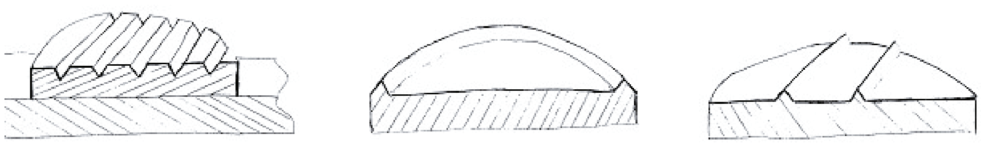
It is impossible to guarantee good contact reliability at the design stage. Contact reliability is the result of a number of precautions taken at the design, production engineering, and manufacturing stages. No single precaution is sufficient to ensure good contact reliability. Good contact reliability is the sum of the precautions taken at each of the stages mentioned above.

1.2. Different possible architectures

At constant contact pressure, contact resistance changes as illustrated below:



1.3. Contact surface shape



Serrated Concave Spiked

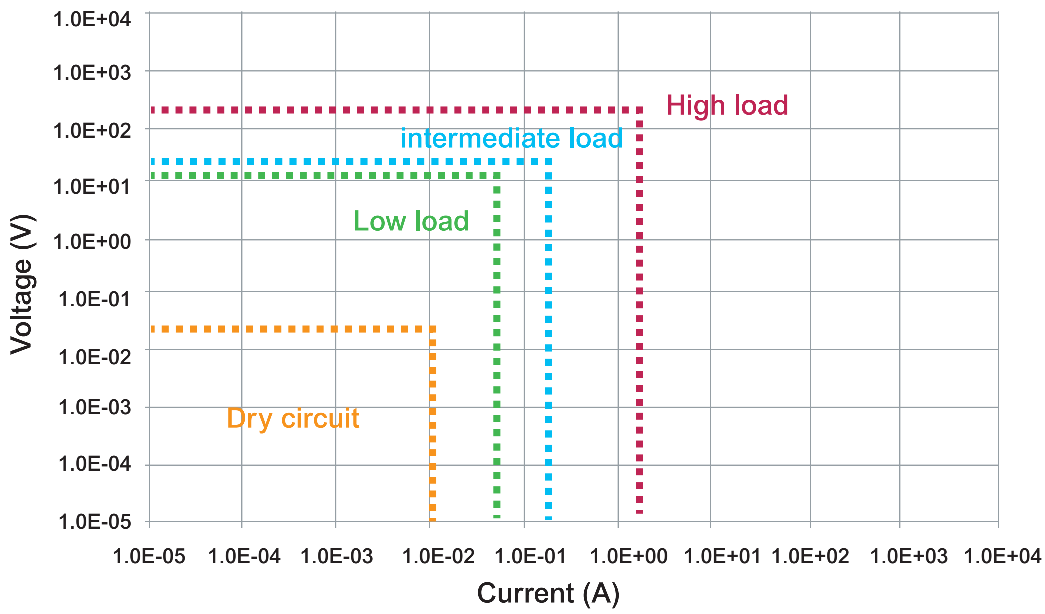
1.4. Producting engineering

- No burrs on plastic parts or contacts
- No dust
- Suitable mold design
- Suitable plastic material
- Centrifugal casting feeders and band feeders are strongly recommended over vibrating bowl feeders with no hopper, which should be avoided

1.5. Operating ranges

Physical measurements like voltage and current have a significant influence on contact resistance and, therefore, on reliability. Each time the electrical circuit is switched off, and, if the voltage is sufficient to generate and electric arc, the electric arc will clean the contact surface.

The following graph shows each operating range.



Dry circuit:

Voltages at which the contact materials would be softened are never reached.

Low load:

There are two significant effects:

- First, when the contact opens, the temperature in the constriction area rises, reaching the melting and, subsequently, boiling points of the contact material, which leads to an increase in voltage at the terminals.
- Second, even if the voltage of the open circuit is lower than the minimum arc voltage, very-low-energy arcs can appear. This causes the chemical substances that are deposited on the surface to decompose. If the arc does not have enough energy to burn the substances off completely, the contact resistance will increase.

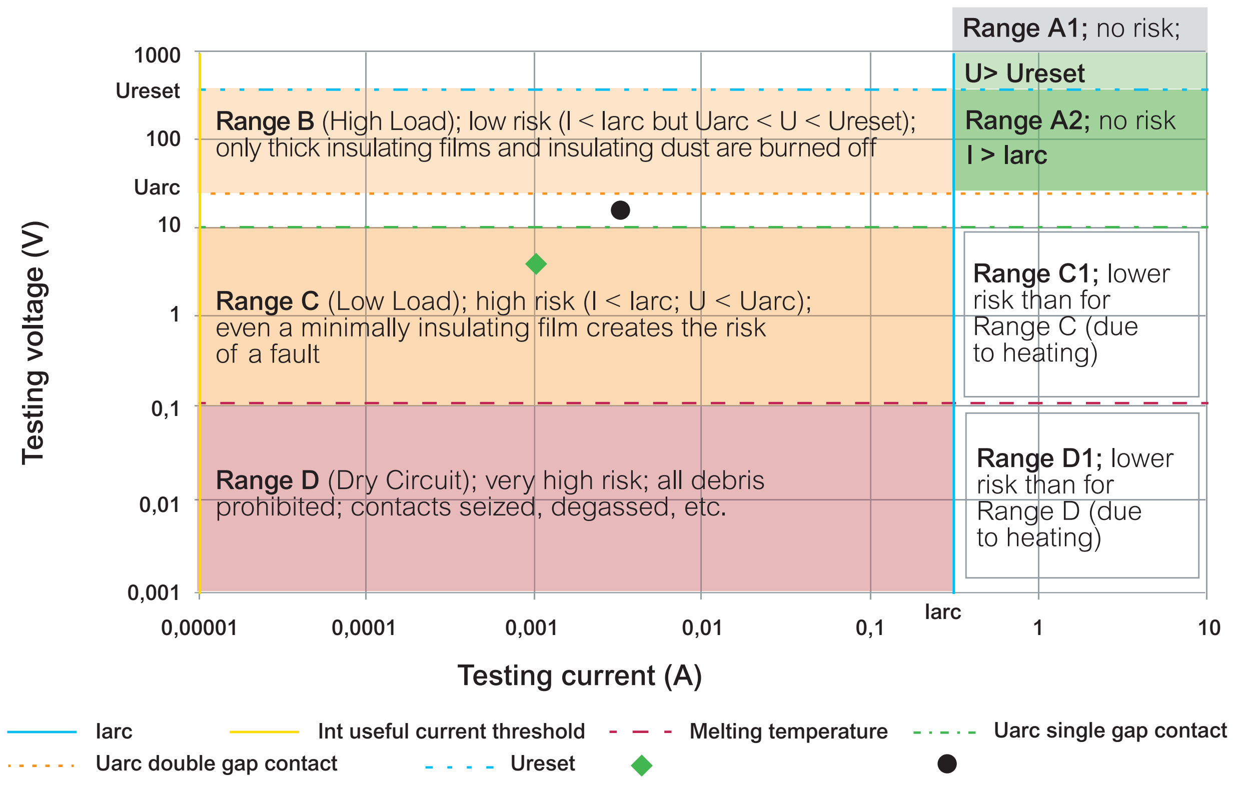
Intermediate load:

VShort (anodic) arcs and discharges from the wires are the most common effects. Depending on the discharge energy, erosion can occur if the arc has enough energy to burn off the carbon deposited on the contacts.

High load:

An electric arc occurs virtually systematically. Depending on the current and voltage, the dominant mechanism is either material transfer or contact erosion.

The issue of contact reliability can only occur in the first two ranges; for the other ranges, contact erosion occurs. As a result, the number of open/close cycles is drastically reduced.



The graph above shows that reliability increases with operating voltage, because it results in the contact surfaces being cleaned during each open/close cycle.

For products not enclosed in cabinets, the immediate surroundings (temperature, humidity, dust, and gases) have a direct impact on contact reliability.

2. Calculating contact reliability

Contact reliability is calculated using an χ^2 analysis.

The total number of times the contacts will open and close during a test is calculated as follows:

$$N^* = \sum Ni$$

N*: Total number of times the contacts of the products being tested open and close before a malfunction.

Ni: Total number of times the contacts of product i open and close before a malfunction.

Therefore, Ni corresponds to the number of times the contacts open and close, either by the end of the test or by the third malfunction.

Therefore, contact reliability λ is calculated as follows:

$$\lambda c = Kc / N^*$$

λc: Contact reliability rate (sans unité) with confidence rating c (60% or 90%)

Kc: Coefficient of the rule χ^2 (dependent on the number of malfunctions during the test and the selected confidence rating, 60% or 90%).

$$Kc = 0.25\ [(4r+1)1/2 + B\ ]^2$$

r is the number of malfunctions

B depends on the confidence rating c

c = 60%, B = 0.253

c = 90%, B = 1.28

For **r** < 25, Kc is given in the table below.

Therefore, the "mid-time to failure" (mc) can be extrapolated; this corresponds to the statistical lifespan (number contactor open/close operations) of the product before failure, with the corresponding failure rate: mc = 1 / λc

If the product is maintainable (parts can be replaced), we refer to "mid-time between failures."

Number of faults	Kc value at confidence index c%	
r	c = 60%	c = 90%
0	0.915	2.305
1	2.020	3.890
2	3.105	5.300
3	4.175	6.70
4	5.25	8.00
5	6.30	9.25
6	7.35	10.55
7	8.40	11.75
8	9.45	13.00
9	10.50	14.20
10	11.50	15.40
11	12.55	16.60
12	13.60	17.80
13	14.60	18.95
14	15.65	20.15
15	16.70	21.30
16	17.70	22.45
17	18.75	23.60
18	19.80	24.75
19	20.75	25.90
20	21.85	27.05
21	22.85	28.20
22	23.90	29.30
23	24.90	30.45
24	25.95	31.60

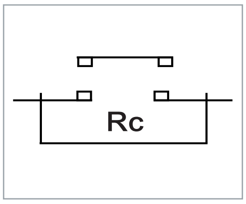
Table of Kc values for **r** < 25

3. Schneider Electric's design choices

TeSys LC1D and LADN have sliding, lubricated, serrated double-gap contacts.

3.1. Architecture and surfaces

Double-gap

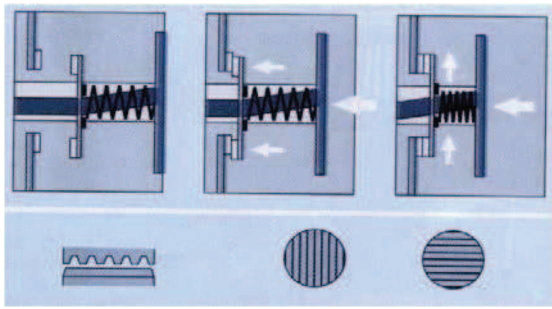


- Opening performance superior to single-gap contacts at identical opening speeds (double reset voltage)
- Sliding (translational motion) contacts (greater contact reliability)
- Opening distance equal to the sum of the two inter-contact distances
- Contact pressure finely controlled (generally by a spring); double the contact pressure of a fork contact

Serrated contacts with perpendicular grooves between fixed and mobile contacts

- Good cleaning of contact surface (debris ends up in the grooves)
- Good geometric repetitiveness of contact points
- High local contact pressure

Sliding lubricated contacts



The contacts are lubricated with a fluorinated oil which significantly improves contact reliability at low voltages.

Advantages of lubricated contacts:

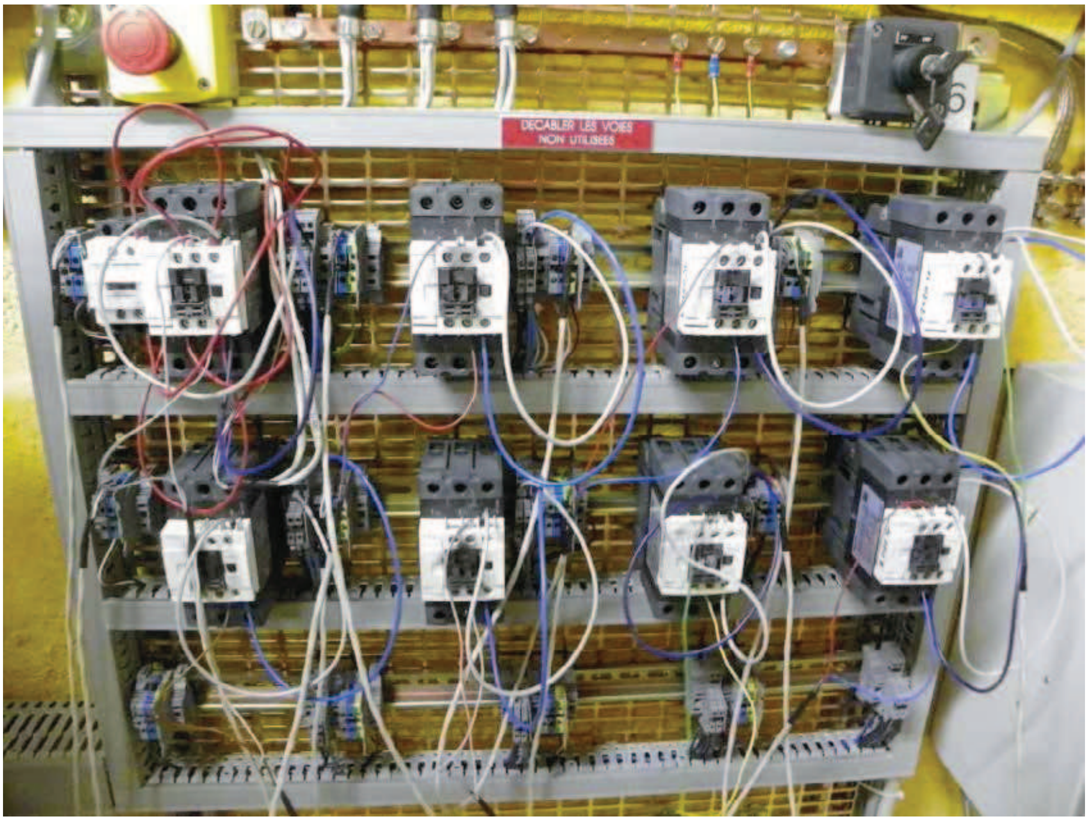
- Improved mechanical operation of the contact
- Protection of contact surfaces from oxidation
- Attenuation (elimination) of fretting-corrosion issues, especially when the contact is designed as a sliding contact
- Low contact resistances: it has been shown that very thin layers of low-viscosity lubricant behave like good electrical conductors; a physically and chemically stable oil on the contacts promotes contact reliability and like-new contact resistance in dusty environments
- Faster contact (static resistance is lower)

4. Schneider Electric's tests and measurements

The purpose of this test is to determine the probability of a malfunction independently of the number of times the contacts open and close.

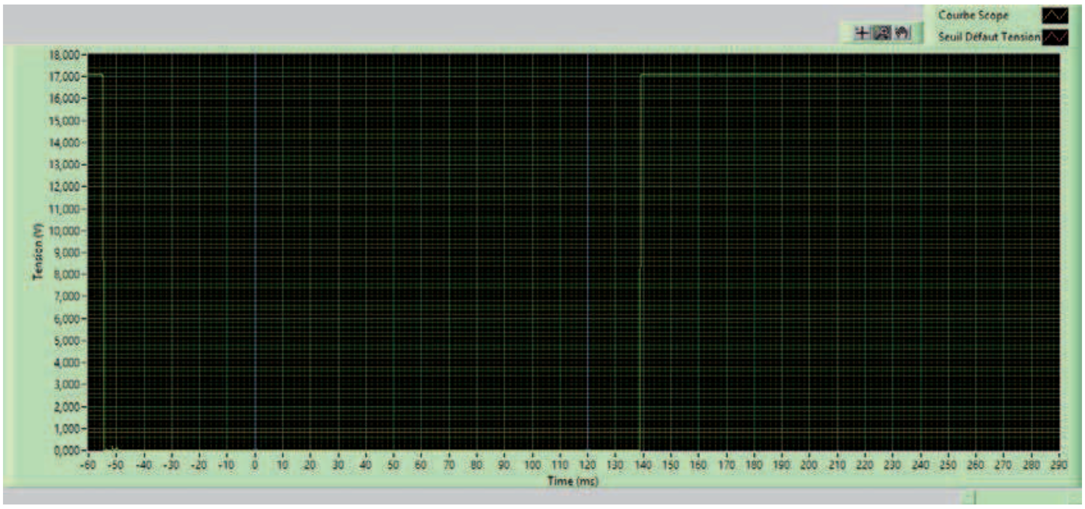
Contact reliability at low voltages (5V or 17V) is described in the standard IEC 60947-5-4 for command-control devices. The principle of the test is to assess, for a large number of open/close operations, the occurrence of the third malfunction resulting in a decrease in voltage of more than 10% of the operating voltage. The test was completed on a large number of products. A Khi2 test is then used to determine the probability of a malfunction.

4.1. Test setup



4.2. Testing method

The tests were carried out on a significant number of contacts over a large number of open/close operations (5 million); however, this is still less than the products' mechanical lifespan. The contacts were closed for 300 ms. The measurement of the drop in voltage started 60 ms after the current was switched on and was measured at 20 ms intervals for 100 ms. The opening of the contacts was checked 40 ms after the open command. The cycle frequency was set at 2 Hz to reduce the duration of the test. The test was considered finished when all products had completed the 5 million open/close operations or had failed.



4.3. Levels of severity

Two levels of severity were used:

- 17V / 3.4mA
- 5 V / 1mA

4.4. Failure criteria

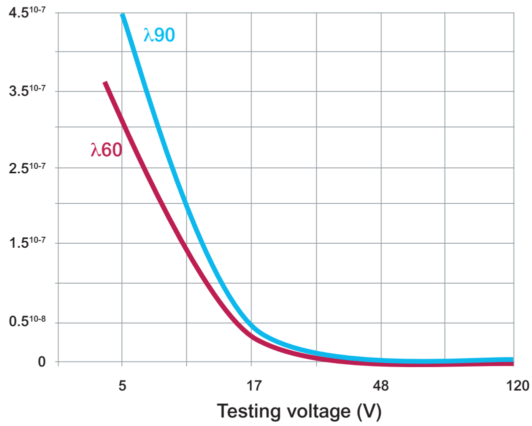
The threshold voltage was 0.85V at the product terminals.

- A drop in voltage greater than the threshold value for at least 1 ms was noted, but was not included in the contact reliability calculations
- All drops in voltage greater than the threshold for more than 5 ms were considered malfunctions
- Any product that malfunctions three times (in a row or not) was considered to have failed and was shut down (for possible tests); the number of open/close operations corresponding to the third malfunction was used to calculate the contact reliability

4.5. Types of failures

Two levels of severity were used:

- Damage to product
- Dust build-up
- Formation of thick films



Reliability function of using voltage

Here, we ran experiments to confirm that contact reliability increases with voltage, as long as we remained within an operating range that did not generate electric arcs when the circuit was switched off. If the arc's energy is sufficient, the issue is no longer contact reliability, but rather electrical durability, with a sharp increase in the curve starting at 48 V.

Conclusion

Schneider Electric's auxiliary contacts offer very high reliability thanks to a patented sliding and wiping mechanism that is currently used every day in an estimated 400 million motor starters worldwide. Schneider Electric's auxiliary contact surfaces are serrated. The sliding motion that occurs when the contacts are opened and closed cleans any carbon deposits off of the contact surfaces. Based on regular factory testing over millions of open-close cycles, the products' contact reliability is in the 10-8 range. This high level of reliability—crucial in the automation industry—is backed by Schneider Electric's broad, deep knowledge of design, plastic materials, and manufacturing processes. In addition, Schneider Electric's double-gap contact architecture delivers a higher contact pressure for the same spring force used in a parallel contact architecture. This has a direct and positive impact on contact resistance and signal quality, crucial for high-vibration applications (railway, etc.).