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Special Publication

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Standard-compliant and functionally-safe engineering design with mechanical auxiliary contacts

New, electronic-compatible auxiliary contact modules *DILA-XHIR11* for the contactor relay *DIL A* and for the most popular contactors *DIL M7* to *DIL M32*, complement the xStart product system [1]. The new auxiliary contacts provide an opportunity to discuss the topic of contact or control circuit reliability. This technical publication additionally examines different auxiliary contact constructions from the point of view of their suitability for usage in safety-related controls.

In control circuits occasional malfunctions can occur even with the use of top-quality switchgear. These difficulties can be avoided by a problem-orientated engineering design approach. In this special publication potential sources of disturbance are highlighted and preventative solutions for engineering design are indicated. Well-known principles of reliability and safety with electrical low-voltage switchgear systems are explained. This publication endeavours to make this topic understandable for all persons who do not have a background in electrical technology.

Information for quick readers

Even highly automated machines and systems cannot be designed without electromechanical components which feature electrical isolation, a high level of safety and excellent performance on the interfaces to the electronic inputs and outputs. Contacts can occasionally cause contact faults due to unfavourable circumstances and conditions. Contact faults must be avoided at all costs as a very high level of availability is expected from machines and systems due to economic and technical safety considerations. Moeller plays its part and provides improved auxiliary contacts, but the design engineer, the installation specialist and the operators must also provide support. The influencing variables are described in this publication as constructive measures, engineering principles and ambient influences.

Different parameters influence the contact reliability

Four aspects influence the quality level of the contact or control circuit reliability of electromechanical switchgear and protective devices on the interface to the electronic systems, and in the circuits with very low currents and voltages:

- Constructive features of the contact element,
- Current and voltage levels which are to be switched,
- Engineering design principles with interconnection of several contact blocks
- and the ambient conditions.

The contact reliability or contact security is not a constant factor, but deviates from circuit to circuit within a certain tolerance. The tolerances can be influenced by the four factors mentioned above. The competence of a switchgear manufacturer is primarily responsible for the first criterion. Over the years there have been various solutions for optimisation of the contact reliability of auxiliary contacts (examples in **Table 1**), which are available as ready made products on the market. The individual solutions include advantages and disadvantages. The most important disadvantage relates to limitations with the relationship between different types of contacts for safety circuits with regard to the reductions in electrical load capability and the frequent limitation of application possibilities, or the absence of electrical isolation (will be explained later).

The term "auxiliary contact" sounds very simple at first. The demands placed on it however are very comprehensive and partly physically contradictory. **Table 2** shows in very simplified form the typical demands placed on the contacts with different product groups which feature different actuation devices. The method of actuation heavily influences the construction of the contact and the remedies to contact reliability problems.

Auxiliary contacts are frequently involved in the mastering of safety-related tasks, e.g. personnel protection with dangerous machines and systems. Hence various safety standards have dealt with the requirements placed on the contacts and have produced new terms which have led to the confusion of many users. New terms have always been associated with the escalation in the requirements and with a more exact description of the relationship and dependance between different types of contacts.

Contacts with electrical isolation for safety functions

One of the most important features of contact-relevant switchgear continues to be the electrical isolation provided by the contacts, which provides a high level of safety, e.g. for personnel safety, and on which the entire safety philosophy is based. The electrical isolation ensures that the isolated conductors on the output side are truly potential free. In contrast to switching with semiconductors it must be noted that a leakage current will flow in the off state and that a dangerous touch voltage may exist on the output.
A second significant difference between mechanical contacts and semiconductor contact elements is associated in the transfer resistance and in the related

heat dissipation. The heat dissipation is about 10 times higher on semi-conductors than on an electromechanical contact for the same current. This aspect plays a significant role with high-power contacts.

Contact types and standard-conform relationships between contacts

The risk assessment prescribed for machines and systems in compliance with the EU machine directive is usually performed by machine specialists. This is why the most well-known and different types of contacts and their peculiarities should be explained here first for the electrical specialist personnel. With the contact types it is initially important to differentiate between main and auxiliary contacts for the sake of the standards. **Main contacts** or **high-power contacts** belong to the **circuit-breaker devices** (e.g. contactors, circuit-breakers). They are designed to switch different types of loads (motors, heating systems, lighting, capacitors, etc.) with different rating data (power, current, voltage) over a suitable lifespan. The demands on the main contacts result from the corresponding product standards, for example from the group IEC/EN 60 947, but also from the construction and installation standards, such as IEC/EN 60 204-1 [2].

Auxiliary contacts are also referred to as **supplementary contacts** or **control contacts (Figure 1)**. They belong to the auxiliary or **control devices** (e.g. control devices, contactor relays, relays). They are also used for auxiliary functions on the described circuit-breaker devices. They are mainly used to signal switching or malfunction states, for interlocking circuits or logic and sequence controls with low to high loading.

Those who are not familiar with the construction principles of switching and protection devices initially assume that the auxiliary contacts always assume the same switch position as the main contacts. However, this obvious assumption is not always possible to realise on the timing front. For example, the linear motions of the actuators of the main and auxiliary contacts may vary in length, so that acceleration path and the slowdown path leads to differing switching time points. The main and auxiliary contacts are no longer switched on and off using the same contact mechanism, at the latest since the switchgear has been developed, constructed and combined as a modular system. Previously the contact paths of auxiliary and main contacts more or less exhibited significant differences with the non-modifiable switchgear, because different voltages, currents and load types with varying arcing conditions had to be mastered, which inevitably

Construction features	Technological and economic aspects		Important criteria for safety applications	
	Advantages	**Disadvantages**	**Positively driven contacts**	**Mirror contacts**
Integrated microswitch	Switch in a switch, introduces a certain enhancement of the degree of protection, can be used for wide current and voltage ranges	See right	Under certain circumstances, if N/O and N/C contacts are available	Probably no
Reed contacts	Attractively priced, space-saving	Vibration sensitive, sensitive to interference, low loadability, short-circuit protection difficult	No	No
Electronic circuits	Wear free, insensitive to soiling, insensitive to vibration	Expensive, voltage supply dependent, outputs frequently potential relevant, difficult short-circuit protection	No	No
New auxiliary contact *DILA-XHIR11* from Moeller	Attractively priced, no limitations in terms of loadability with current and voltage values	For 2 contacts the space of 4 "normal" contacts is required	Yes, for use in safety circuits	Yes, for use in safety circuits

Table 1: Different example solutions for auxiliary contacts with the main advantages and disadvantages. In safety applications positively driven contact blocks, or even mirror contacts are required

Construction features and influences which are to be controlled	Demands on the auxiliary contact with the product groups			
	Contactor relay *DIL A*	**Timing relay** *ETR 4, DIL ET*	**Contactor** *DIL M*	**Overload relay** *ZB*
Actuation method	Electromagnetic	Electromagnetic	Electromagnetic	Thermodynamic
Mechanical/electrical lifespan	Very high	Very high	Very high	Low
Operating frequency	Normal to medium	Normal to high	Low to normal	Very low
Contact force	Medium	Low	Medium to high	Very low
Contacts per unit	4, 6, 8	2 changeover contacts	1 ... 8	2
Influences from the basic unit	Are part of the basic unit	Are part of the basic unit	Shock	Shock from the contactor
Mainly loading from the environment	Normal	Normal	Normal	Normal
Preferred location	Control panel	Control panel	Control panel	Control panel

led to the necessary contact clearances (isolating gaps) and contact forces. The differences in the switching paths, e.g. compensated using springs, with the effect that auxiliary and main contacts are actuated with more or less a large time delay.

A fundamental principle of the safety circuit is that the switching state of the auxiliary contacts will close safely to the switching state of the main contacts. Actually even more is desired. If an auxiliary contact closes and an indicator light switches on, one wants to assume as a result that the corresponding motor is now rotating. The amateur would assume that if the indicator light does not light, it can be safely assumed that a motor which they can probably not see does not rotate. This conclusion is not valid and dangerous, because a series of faults in the circuit are possible (e.g. cable breaks, defective lights, welded main contacts, etc.), which can also lead to the indicator not lighting up. With special safety-relevant factors it may be necessary to implement redundant control circuits[1] or the equipment may be monitored with additional protection systems (e.g. zero-speed monitors, speed transducers) directly on the equipment.

In earlier days when only electromechanical contact elements were available, the small differences in the switching times or contact sequences were purposely used and **early make** or **late break** auxiliary contacts or **overlapping contacts** were relevant (**Figure 2**). These small differences with a very large spread are rarely used in the age of electronic circuitry and now electronic timing relays with definable and exact timing are used.

With early-make contacts and late-break contacts the next differentiation with the contact types has been mentioned. It is a matter of the reaction to an actuation function. There are **N/O contacts**, which are closed by the mechanical or electromechanical actuation of a switching or protection device. They are open in the quiescent state of the base unit in contrast to an **N/C contact** which is closed in the quiescent state and which opens by actuation of the base unit. Ultimately a differentiation is made between the duration of the actuation of a contact between **permanent contacts** and **pulse contacts**, where switching can be processed differently. In terms of the contact reliability and the effects of an uncertain contact in terms of this publication, it is still interesting if the effect of a contact fault can be eliminated by the repetition of a switching command. A manually actuated control circuit device can usually be actuated again after a fault. Other switching commands occur on an automated basis, or are process dependent or dependent on a certain position of a machine. In these cases the contact can frequently not be made or can only be made with a lot of effort. In particular, contact faults which only occur infrequently are not desirable and are therefore very difficult to localise.

For engineering the important principle is that the auxiliary N/C contact and the auxiliary N/O contact of a device can not close simultaneously (normal demand, assured with positively operated contacts) – with the exception of the special version “overlapping contacts”.

[1] Redundancy = use of more than one device (system), to ensure that when a device (system) malfunctions another will assume its function.
Terms: full or partial redundancy, online redundancy, off-line redundancy

	Motor-protective circuit-breaker *PKZ*	Circuit-breakers *NZM*	Control circuit devices *RMQ 16 /22*	Position switches *AT*
	Stored energy mechanism	Stored energy mechanism	Manually actuated	Machine actuated
	High	Medium	Medium	Very high
	Low to normal	Low	Normal to high	Low to very high
	Low to normal	Medium to high	Low	Medium
	1... 6	2, 4, 6	1 ... 6	1, 2, 3
	Shock	Shock	Heat of the indicator light	Are part of the basic unit
	Normal to high	Normal	Normal to high	Normal to very high
	Control panel, small enclosure	Control panel	Small enclosure, on machine	On machine

Table 4: **Auxiliary contacts of different switching and protection devices are loaded in different manners by the basic units and the main applications. The approximate ratings are mainly true for the main applications of the devices.**

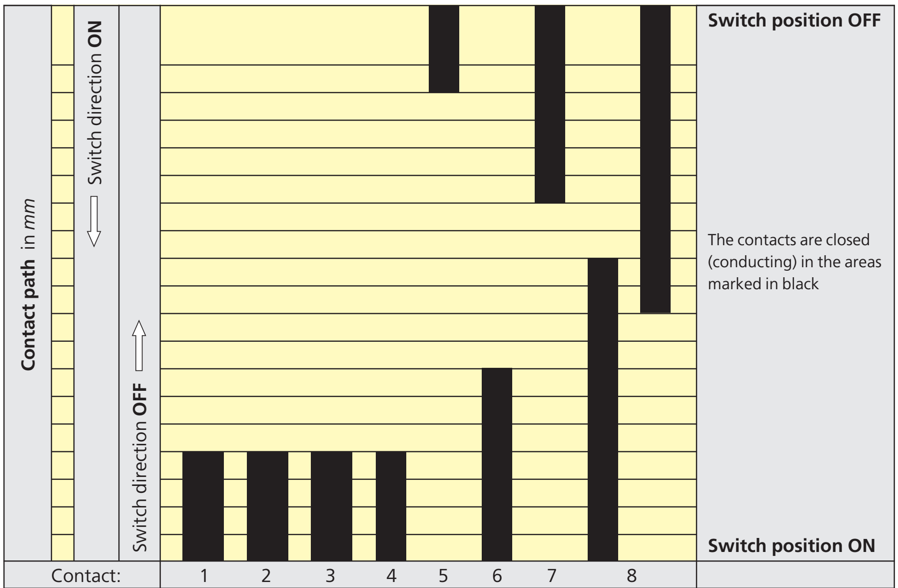
Figure 1: **Example for switching and protection devices with main or power contacts or / and with auxiliary contacts**

Furthermore, it also applies that an auxiliary N/C contact opens before the auxiliary N/O contact closes (**Figure 2**). In principle, the engineering should ensure that a switch-off command always has priority before a simultaneous switch-on command. In order to ensure this, control circuit devices for switch on and off are mutually electrically interlocked.

Functional safety of the contacts has economic and technical aspects

In addition to the easily comprehensible economic consequences of a reduction in the availability of a machine or system, potential safety problems should be avoided [3]. The employer's liability insurance association are primarily concerned with the personal safety of the machine operators on power operated presses. A milestone was the so-called "Press safety controls". With this important step in electrical safety technology of machines, the definition of the first term defining the relationship between different contact types was undertaken. The employer's liability insurance association guideline ZH1/457 coined the term "**positively driven contacts**", which has been replaced in the standards in the meantime by the term "**positively driven contact elements**". Even today after more than 30 years, the meaning of this term is not comprehensively known among all the specialists who are involved in the machine safety technology field.
The confusion has been compounded by incorrect translations in other languages and unforgivable mistakes by contradictory definitions in standards which have appeared later.

Positively driven contact elements, to IEC/EN 60 947-5-1, Annex L [4]:
used, e.g. for self-monitoring in machine control circuits. They make an exclusive statement concerning the relationship between different types of **auxiliary contacts on one and the same contactor relay** (devices where the actuation forces are generated internally). **It is necessary over the entire lifespan to exclude that the combination of n auxiliary N/O contacts and m auxiliary N/C contacts may never be closed simultaneously on the same device.** One critical aspect is the possible skewed alignment of the contact bridge (**Figure 3**), if one of the outer contacts welds. There were long discussions in the standardisation committees relating to whether the required minimum clearance between contacts should be measured or verified by an impulse voltage test. The current standard requires an impulse voltage test on "artificially welded" devices.



1, 2, 3	Main contacts:	N/O contact	
4	Auxiliary contacts:	N/O contact	6...8 As the requirement for early-make and late-break are not defined, generally an overlap is implemented
5		N/C contact	
6		Early-make contact, early-make N/O	
7		Late-break contact, late break N/C	
8		overlapping contacts	

Figure 2: Contact sequence diagram for representation of the relationship with the actuation of differing contacts of switchgear. In principle normal N/C contacts will open before normal N/O contacts close. Early-make contacts, late-break contacts and overlapping contacts are usually used today in special cases only.

A contactor relay can have several groups of positively driven contacts simultaneously as well as the mirror contacts described later. Positive operation must be indicated in the circuit diagram by a parallel double line which connects the filled out circles on each symbol of the positively driven contacts. An example from the standard is shown in **Figure 4**.
A manufacturer specification on the device does not introduce any clarity as under certain circumstances a device can feature both positively driven as well as non-positively driven contacts, and therefore the specification of positive operation is preferably made in the manufacturers catalogue only.

Switchgear with external actuation (e.g. pushbuttons, position switches) can not feature positively driven contacts according to the standard because they do not feature a maximum actuating force. With a large actuating force it is possible to bend every contact and achieve that N/C and N/O contacts are closed simultaneously. With these types of devices only **control circuit isolator with positive operation** to IEC/EN 60 947-5-1, Annex K [4] can result. This term signifies that a "welded contact" can only be broken apart by a sufficient force. This assumes that the force is transferred directly between the actuation element and contact and without elastic elements (typical: control circuit device Emergency-Stop).

The switchgear manufacturers contribute to the uncertainty with the users. Whereas the term **positively driven was used exclusively with contactor relays** in the standards, there was

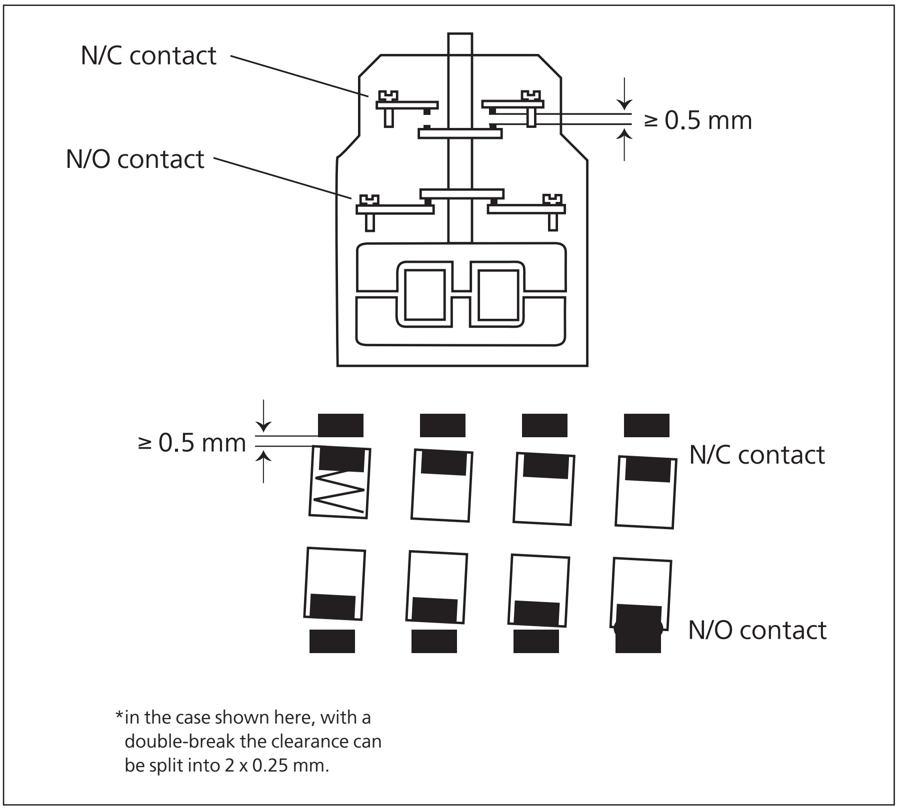


Figure 3: If for example the outer right make contact welds with a contactor, the contact bridge of the switched off contactor may skew. With "positively-driven contacts" it is demanded that the break contact does not close in this case, but rather, that a clearance of 0.5 mm is retained between the contacts for the entire lifespan of the contactor. Various safety circuits are based on the assumption that the break contact and make contact of a contactor can never close simultaneously.

mention of "positively driven contacts" with contactors in their advertising. This was due to the fact that the contactor relay and small contactors (< 3 ... 4 kW) are generally identical in construction and differentiated primarily in the use of the standard conform designation of the terminals. The advertising had the effect that the users referred incorrectly to the relationship between main circuit N/O contacts and auxiliary N/C contacts as "positively driven contacts". This may be the case on small contactors, on larger contacts the difference between the contact forces with main and auxiliary contacts is so large that the conditions for positive operation can no longer be assured. Here too unwanted deformation can occur during a malfunction. **According to the standard the term "positively driven contact elements" makes no statement concerning the parity of the switch position with main and auxiliary contacts, but rather refers exclusively to the auxiliary contacts.**

Positively driven contacts are useful for a safe switching of the logic functions within safety-related circuits (safe interrelationship of auxiliary contacts). However, they do not fulfil the previously described expectation of the user in terms of making a statement concerning the switching state or a malfunction of the main contacts. Here there were discussions for a long period of time concerning the definition "incomplete positive operation" or a "positively driven operation in a single direction" due to the differing force ratios between main and auxiliary contacts. The solution which was finally agreed and used in the standard was **mirror contacts**. **This contact definition for the first time made a statement concerning the relationship of the switch position on main and auxiliary contacts.** Hereby it can only by a statement in one direction **concerning the relationship of main circuit N/O contact to an auxiliary N/C contact.**

Mirror contacts,
to IEC/EN 60-947-4-1, Annex F [5]:

The mirror contact is an N/C contact, which can not be closed simultaneously with the main contact. The test is undertaken on artificially welded contactors. The open state of the mirror contact is verified during an impulse voltage test or a contact clearance of at least 0.5 mm must be measured.
A contactor may feature several mirror contacts. At the current time mirror contacts are known and standardised exclusively on contactors. "Mirror contacts" should not be confused with "positively driven" contacts. Mirror contacts can be simultaneously compliant with the requirements of "positively driven contacts" to IEC/EN 60 947-5-1.
Mirror contacts must be clearly marked on the device or in the documentation of the manufacturer. If a symbol is used to identify the mirror contact it must correspond with the representation in **Figure 5**.
A designation of the contact in the circuit diagram is not stated in the standard in this case as opposed to the "positively driven contacts".

A typical application for mirror contacts is to provide a highly-reliable monitoring for the (switching) state

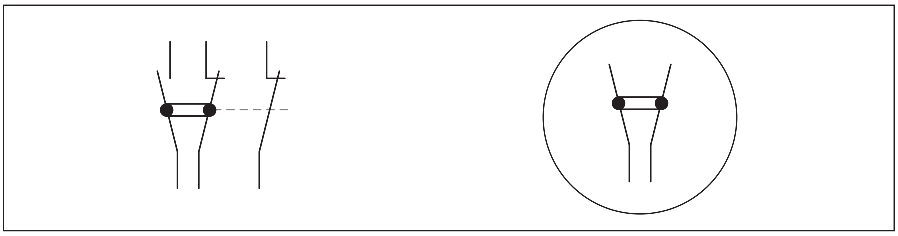


Figure 4: Left: Example of a standard compliant representation of positively driven N/O and N/C contacts and a non positively driven N/C contact in a circuit diagram. Right: Example of a possible marking on a device, for devices which also contain positively driven contacts.

of the contactor in control circuits of machines. However, the mirror contacts should not be relied on as the only safety device. The standard recommends self-monitoring of the mirror contact. The standard implies that the main contacts are N/O contacts which is not always the case. Unfortunately it is evident that the terms “positively driven contacts” and “mirror contacts” have been edited to the disadvantage of the user by different standardisation committees.

The new auxiliary contact alternative *DILA-XHIR11* rounds off the product range

The new auxiliary contact module *DILA-XHIR1* provides 1 electronic-compatible auxiliary N/O contact and 1 electronic-compatible auxiliary N/C contact with significantly enhanced contact reliability, in the xStart system for a contactor relay or for contactors with frame sizes *DIL M7* to *DILM 32*. It features the well-known screw terminal technology known in the system and the terminal designations for contactor relays to DIN EN 50 005 (N/C 61-62 and N/O 53-54). The contactor relay base unit features 4 other “normal” contacts and each contactor features 1 “normal” auxiliary contact in the base unit. These “normal” contacts can be N/C or N/O contacts as required.

The particular highlight of the auxiliary contact module *DILA-XHIR11* is that its contacts are compliant in the base unit to the described **positive driven** requirements regarding the contacts to one another and to the auxiliary contacts. If the module is combined with the mentioned contactors, the

Figure 5: If mirror contacts are identified with a symbol, the symbol shown must be used. In the standard a clear identification of the mirror contacts by the manufacturer on the device and / or in the documentation is demanded. Identification in the circuit diagrams is not mentioned in contrast to the “positively driven contacts”.

auxiliary N/C contact in the module also fulfils the demands of a **mirror** contact relative to the **N/O main contacts** in the base unit. Base units and auxiliary contact modules are suitable as a result of these features for use in safety-relevant controls with the additional benefit that the contacts of the auxiliary contact module have been optimised for switching of small currents and voltages. They are also excellently suited for example, to safely switch 1 mA at just 5 V (signal currents) on the input of an electronic control under unfavourable ambient conditions. At a contact loading with U = 17 V and I = 5.4 mA (control current) a failure rate $\lambda < 10^{-8}$ is the result. This specification means that statistically only one 1 switching malfunction can be assumed after 100 million switching operations.

A very important feature of the new auxiliary contact with electrical isolation is that it can be used for the “large” currents and voltages of “normal” auxiliary contacts. For this reason a solution involving the internal parallel connection of auxiliary contact elements in separate contact chambers, with four independent contact points has been selected. This means that the same contacts can also switch AC-15 currents up to 6 A and operating voltages up to 500 VAC, or can switch DC voltages up to 250 VDC and DC-13 currents up to 10 A. The thermal continuous current $I_{th} = I_{AC-1}$ at an ambient temperature of 60 °C is 16 A. The contacts can even be protected against welding with 10 A gL fuses. This wide field of application eliminates other well-known solutions such as gold-plated contacts, as the gold is no longer present after just a few switching operations. Parallel connection of contacts in separate contact chambers makes simultaneous occurrence of even minute levels of impurities at several contact points much more improbable. The contact reliability is increased by a factor of 500 ... 2000. Even the “safe isolation” feature to DIN EN 61140 [6] with reinforced insulation which is demanded in the chemical industry, is fulfilled with “normal” auxiliary contact modules up to a rated insulation voltage of 690 V. Of course the new auxiliary contact *DILA-XHIR11*, with the same price level as “normal” auxiliary contact modules is approved by the UL and CSA as a device for world markets for use in North America. It is also assigned with the CCC mark for use in China. The combination of all these important safety features with a universal area of application and at a “normal price” can be found on very few of the “special auxiliary contact” solutions for enhanced contact reliability or electronic compatibility on the market. Most of these offers are pure “specialists” which can be used for very few applications.

Current and voltage level influence the contact reliability

The following applied until the introduction of electronic control systems at the start of the 60’s: *“A high control voltage, e.g. 230 V, generally results in a high control circuit reliability so that in contrast to low-voltages (e.g. 24 V) a control circuit reliability calculation was unnecessary”.* This statement still continues to apply today if the use of a high control voltage is possible. Higher control voltages offer additional benefits, and at a higher voltage the required control currents are lower and they result in a lower voltage drop and often require smaller cross-sections. The generation of an AC control voltage is frequently cheaper than a DC voltage. However, the inputs and outputs on electronic systems for low voltage and current levels are cheaper to implement. As the control circuit reliability in today’s highly automated manufacturing and processing systems is very significant, the benefits of electromechanical and electronic components – as with the auxiliary contact modules *DILA-XHIR11* – have converged from a technological point of view. At a failure rate of $\lambda < 10^{-8}$ a calculation of the contact reliability and failure probability is superfluous for most applications which operate today using the very popular 24 V control voltage.

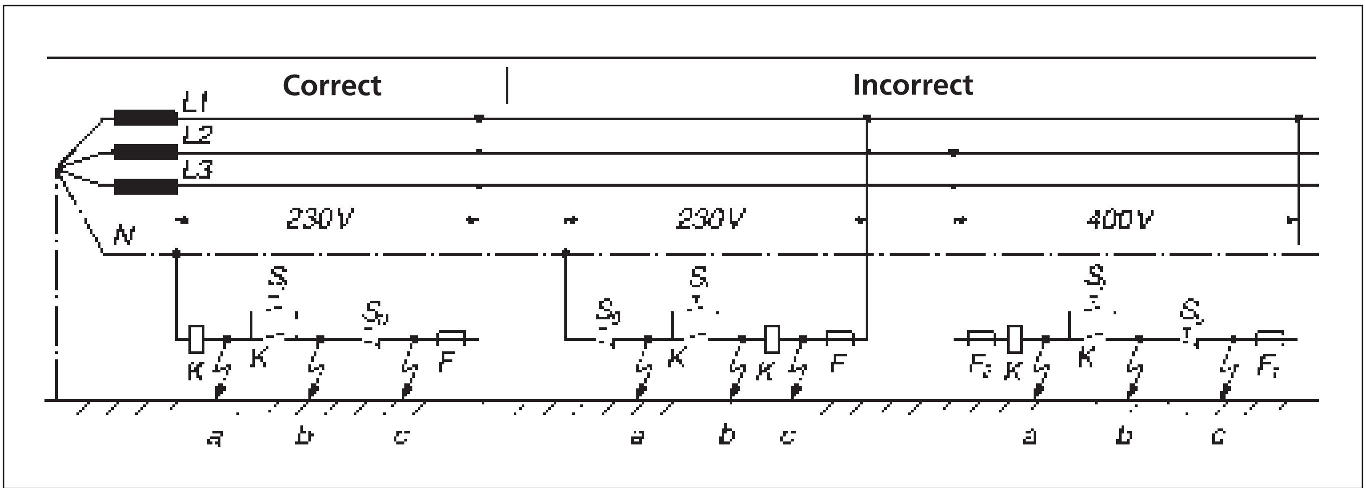
Technical usage of different contact types in circuits

Impulse and 2-wire control require different handling methods in a circuit. There are cases, such as *inching duty* for example, where the motor should only run as long as a pushbutton is manually actuated (e.g. control of shutters and louvres). This is the simplest method of actuation. With the louvre control mentioned, a reversing circuit is required in order to move the louvres in the opposite direction. With these types of circuits, opposing commands for “open” and “close” are mechanically or electrically interlocked to avoid short-circuits.

In cases in which the motor should continue to run independently of the duration of actuation, e.g. until an end position is reached, a contactor has to be maintained (for louvre controls with low powers, operation is undertaken with a small electronic circuit which ensures the self-maintenance function). This is called *three-wire control with self-maintenance*. If an interruption in the voltage occurs on these circuits, the drive will remain stationary, the self-maintenance is interrupted and the drive will not restart after voltage recovery. This behaviour is required for most machines in order to eliminate the dangers posed by an automatic restart (*with automatic reset*).

It is possible to operate with 2-wire control (latching switch) only on systems where an automatic restart does not present a danger after a voltage recovery. This type of equipment includes for example compressors, pumps, heating or lighting (the danger should be clarified on a case by case basis). Even in cases where there are no safety considerations when operating with two-wire control, it is important to note that many loads may switch on simultaneously after a voltage recovery. This can lead to tripping of current-dependent trip-release mechanisms due to the inrush current peaks which could eventually lead to the next fault.

Machines and their controls have become more complex with the increase in automation. Automation has lead to an increase in the incidence of two-wire control, which is not always in the form of a latching switch. In many cases spring-return switches operate like two-wire control, e.g. position switches which are actuated by cams or discs. With two-wire control one is posed with the task of preventing an automatic restart of machines and systems. This is implemented by routing the control voltage via a contactor relay with a pulse control circuit and self maintenance behind the control voltage transformer. If the voltage drops out the entire control is interrupted at this central point, an automatic restart is prevented



<table>
<tr><td rowspan="2">Earth fault</td><td colspan="6">Effects with earth fault before and after switch on</td></tr>
<tr><td>Before</td><td>After</td><td>Before</td><td>After</td><td>Before</td><td>After</td></tr>
<tr><td>a</td><td>Without effect</td><td>F blows</td><td>Without effect</td><td rowspan="2">Contactor can no longer be switched off by “off” pushbutton</td><td>Coil on 230 V, usually no pickup, danger of de-struction</td><td rowspan="2">F blows. Coil remains on 230 V, can no longer be switched off by “off” pushbutton</td></tr>
<tr><td>b</td><td colspan="2" rowspan="2">F blows</td><td>Contactor switches on without command</td><td rowspan="2">F blows</td></tr>
<tr><td>c</td><td colspan="2">F blows</td><td>The same however generally without damage</td></tr>
</table>

Figure 6: The position of the individual switchgear device influences safe operation. Examination of correct and incorrect positioning with clarification of the consequences of a fault scenario

and undefined switching states for the entire control system are avoided. Examples of circuits are contained in the *Moeller* wiring manual and the *Moeller* safety manual.

Position of the equipment and number of contacts in a control circuit

The general sequence of the equipment in modern control circuits is not random, but rather is intended to offer the greatest possible safety during a malfunction. It is assured that the circuit cannot be interrupted and that a circuit can be shut-down by an earth fault. **Figure 6** shows and explains the correct design and clarifies the problems of incorrect design. In principle the contactor coil should always be connected to the neutral pole or a comparable conductor after a control transformer or power supply.

Unfortunately today you can still see many circuit diagrams where too many contacts are connected in series. This is a serious engineering design fault in many respects, as the voltage drop can be very large due to this chain which can mean that there is not enough pickup voltage available for a contactor to be switched on. This is particularly problematic if the cables between the individual contacts also exit the control panel, and for example, are used in emergency-stop circuits which are hundreds of meters long. The author has seen circuit diagrams with 40 contacts connected in series. How should a faulty contact be localised? If many contacts are necessary for example, 6 contacts should be placed on a contactor relay and one contact of this contactor relay should be should be connected in series with a further small number of contacts. Thus a relatively clear number of contacts are connected to the full control voltage. The number of contacts used can be larger with a higher control voltage than with a low voltage, but the ambient conditions must also be considered. It can be opportune in critical cases to connect contacts in parallel and then to connect the contact pairs in series.

Improvement of the contact reliability of relay outputs

Included are limit value encoders with low-power relay outputs, such as thermostats, pressure switches, various regulators, etc. integrated into the circuits. Here there is a danger that the relay outputs may chatter due to a poorly set hysteresis value and exhibit a very high operating frequency. Both malfunctions unnecessarily reduce the life of downstream contactors and other equipment. In order to avoid these types of faults we recommend the use of off-delayed timing relays, e.g. *ETR 4*, with short time ranges in order to introduce a little time-lag into the circuit. At the same time timing relays act like a contact protection relay for the regulator due to their low power consumption. It is possible to use a thermistor machine overload relay instead of a timing relay where the regulator contact is connected to the terminals for the sensor cable instead of the thermistor sensor.

Consideration of ambient influences on the contact reliability

Switching and protection devices can not be manufactured so that they are perfectly sealed, as the switching processes require a certain amount of pressure equalisation which is dependent particularly on the current and voltage levels involved. A certain amount of circulation is required for temperature equalisation. Most switching and protection devices are usually IP20 devices when considered from the front end, with the terminals requiring significantly large apertures in order to connect the required conductors. Labyrinths are used on the construction design side to prevent the ingress of dirt and to simultaneously guarantee the required air-gap and creepage distances. IP20 means however, that practically all devices must be enclosed, e.g. installed in a control panel or in an insulated enclosure. This is also undisputed.

Regardless of these facts a lot of dirt can sometimes be found in the devices when contact reliability problems are analysed. It is frequently underestimated how much dirt gets into the interior of the device during the commissioning with open control panels. The installation phase is also critical if the intended floor covering has not been fitted to the hall or access to the hall, or when a lot of drilling takes place on the open control panel. Some electricians try to remedy the dirt in the control panel by blowing it out with pressurised air. Unfortunately small particles of dirt are then blown into the switching and protection

Figure 7: The safety relay ESR 4-.. in a 22.5 mm wide enclosure is available from Moeller as a processing alternative for standardised safety circuits. Space is saved in comparison to the parallel connection of several contactor relays and the wiring and testing expense is reduced.

devices. Almost all switchgear have a minute quantity of oil which attracts and binds fine dust particles. The mix hardens to form a non-conductive layer which leads to contact problems. A high level of cleanliness is required during installation and commissioning. Many control panels are ventilated using external fans. Where does the air from the fans come from? In America the installation is undertaken with conduits which are flanged directly to the control panel and which attract the dirt from far away due to the draught which is created.

Safety relays for standard safety-relevant tasks

In the area of safety technology on machines and systems there are standard tasks which have often been solved in the past by the interconnection of several contactor relays and even by using timing relays. Moeller provides a series of safety relays with the designation *ESR 4-*… (**Figure 7**) as a processing alternative for these tasks. These relays with a width of 22.5 mm featuring a BG certification (German employers liability insurance) and GS mark (German safety tested) and require less space in the control panel and the wiring and test expense requirement is reduced.

Summary:

Moeller provides the new auxiliary contact module *DILA-XHIR11* with enhanced contact reliability.
The electronic-compatible modules enhance the fail-safety of systems where a large amount of dust is expected to be a factor and where only small currents in conjunction with a low voltage are to be switched. The modules excel simultaneously by a high level of loadability which enables universal use. Highlights are the provision of "positively driven contacts" and "mirror contacts" for standard compliant use in safety-relevant controls. The contacts with electrical isolation can be protected by gL fuses up to 10 A without having them weld due to a short-circuit. This document provides some impulses for engineering design and commissioning taking the subject of contact reliability into account in order to enhance the availability of machines and systems together with the switchgear manufacturers.

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