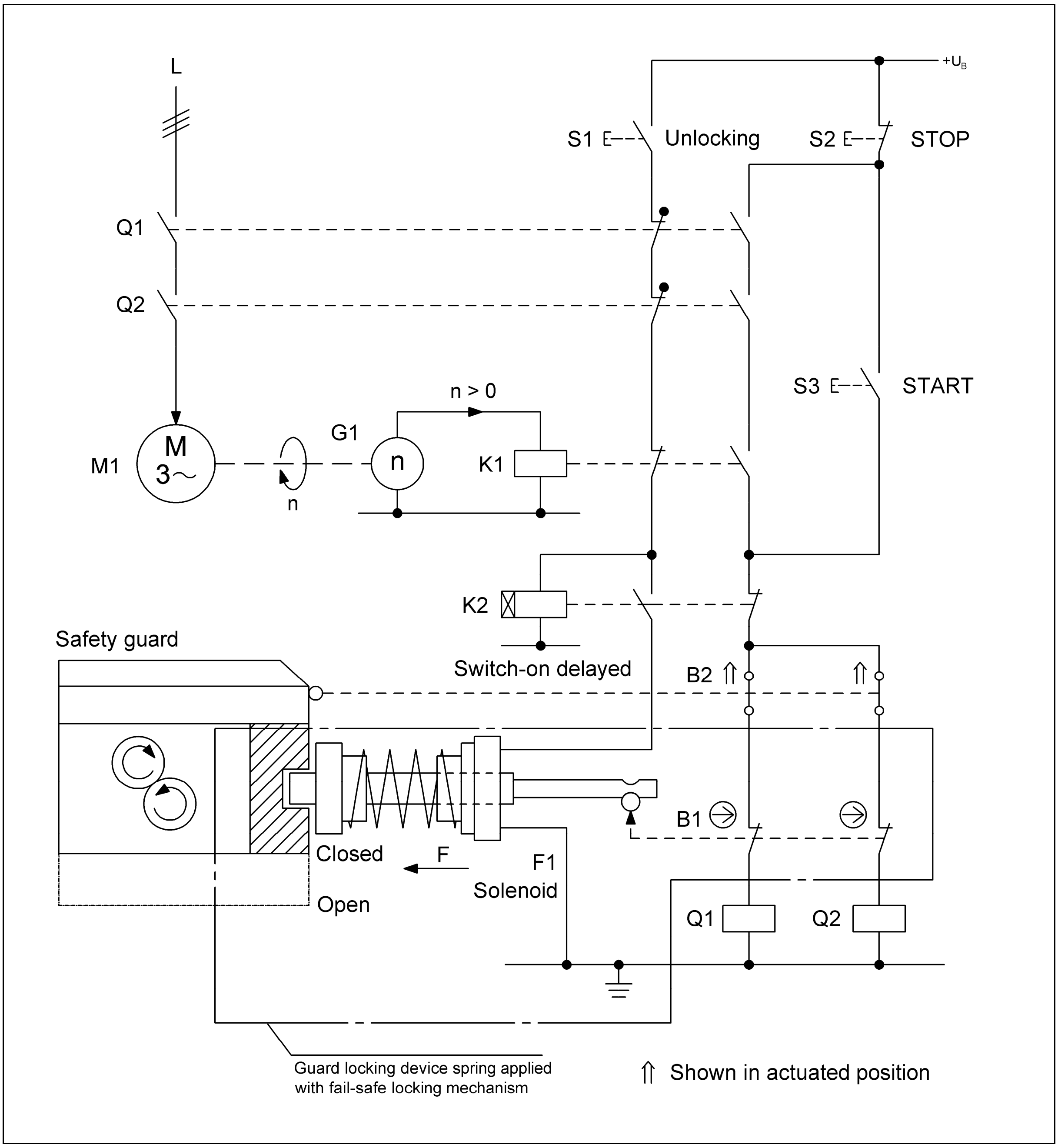
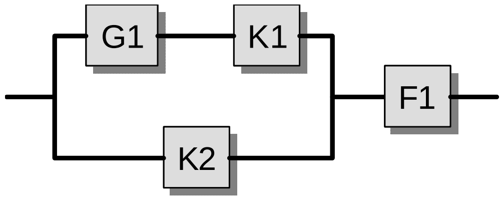
8.2.19 Interlocked guard with guard locking – Category 3 – PL d (Example 19)

Figure 8.34:
Guard locking on a safety guard employing relay technology – Category 3



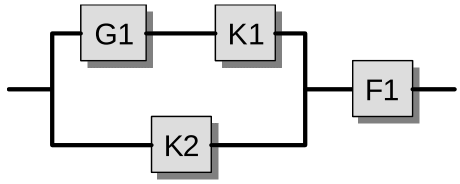
Safety functions

- No deactivation of guard locking at speeds greater than zero
- Prevention of unexpected start-up from rest whilst the safety guard is open



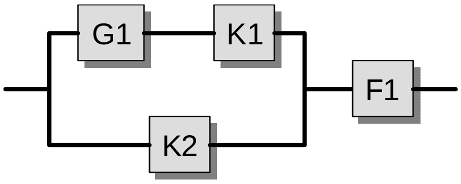
Functional description

- Access to hazardous movement is blocked by a safety guard with guard locking until the moving part has come to rest. The guard is closed by a positive-locking, spring-actuated safety bolt, which is withdrawn electromagnetically for opening of the guard. The position of the locking bolt is monitored by the integral position switch B1; the position of the safety guard is monitored in addition by the position switch B2, in order to increase the immunity to bypassing. The interlocked guard with integral spring-actuated guard locking also features a fail-safe locking mechanism.
- The hazardous movement can be initiated from the start button S3, only with the safety guard closed and with the locking bolt pushed in by spring force. In this position, position switch B1 is released, position switch B2 actuated. Under these conditions, the break contacts of B1 are closed, as are the make contacts of B2. Connection of these contacts in series enables the actuation of the motor contactors Q1 and Q2. The safety-related block diagram for the safety function “prevention of unexpected start-up from rest when the safety guard is open” (not shown here) therefore comprises two redundant channels, B1-Q1 and B2-Q2, where the simplification on the safe side is employed. Alternatively, B1-Q2 and B2-Q1 may be selected. Should these two models yield different values for the $MTTF_d$ per channel, the higher $MTTF_d$ can be used for calculation of the probability of failure.
- Opening of the safety guard during the hazardous movement is prevented with single-fault tolerance. This is achieved by inclusion of the following in the actuation circuit for the solenoid F1: one break contact (mirror contact) each of the contactors Q1 and Q2 and of the zero-speed relay K1, which acts upon the speed information from the tachometer G1 and the make contact of the contactor K2 with switch-on delay.
- Opening of the safety guard during coasting down of the motor following actuation of the stop button S2 and of the unlocking button S1 is prevented with single-fault tolerance. This is achieved by the break contact of the zero-speed relay K1 (based upon the speed information from G1) and the make contact of the contactor G1 with switch-on delay being included in the actuation circuit of the solenoid F1 (see safety-related block diagram).
- Once the motor has come to a halt (Q1, Q2 and K1 have dropped out), actuation of the unlocking button S1 causes the contactor K2 with switch-on delay to be actuated, the solenoid F1 to be activated, and thus the safety bolt to be withdrawn from the safety guard. Whilst the safety guard is open, the position switch B1 remains positively actuated and bypass-proof. Unexpected start-up from rest is also prevented by the position switch B2 (not actuated).



Design features

- Basic and well-tried safety principles are observed and the requirements of Category B are met. Protective circuits (e.g. contact protection) as described in the initial paragraphs of Chapter 8 are implemented.
- The electrical lines are laid in the electrical compartment or take the form of separate multicore cables.
- The contactor relays K1 and K2 possess mechanically linked contact elements in accordance with IEC 60947-5-1, Annex L.
- The contactors Q1 and Q2 possess mirror contacts in accordance with IEC 60947-4-1, Annex F.
- A stable arrangement of the protective device is assured for actuation of the position switch.
- The position switch B1 features direct opening action in accordance with IEC 60947-5-1, Annex K.
- The interlocked guard implemented in the circuit (broken line in Figure 8.34) includes both the guard locking device with the spring-return release solenoid, and the position switch B1 required for position monitoring of the safety bolt and the safety guard. These are housed in an enclosure and therefore are not accessible from outside.
- The spring of the guard locking device is a well-tried spring to EN ISO 13849-2, Annex A.3. In addition, the spring is permanently fail-safe to EN 13906-1. The criteria set out in GS-ET-19, Section 5.5.1 are observed. The solenoid F1 does not pick up without voltage: with simultaneous fault exclusion for the fault assumption “breakage of the blocking device”, this therefore results in exclusion of dangerous faults for these elements altogether.
- The design arrangement of the fail-safe locking mechanism for the guard locking device assures that the safety bolt cannot assume the blocked position (guard locking position) whilst the safety guard is open.
- Not shown in Figure 8.34 are the additional functions integrated in a guard locking arrangement of “emergency unlock” and “escape” for deliberate manual opening of the protective device in the event of a hazard: these functions act positively upon the blocking device without tools and irrespective of the operating state; refer in this context to the test principles of GS-ET-19.
- The standard component G1 is employed in accordance with the instructions in Section 6.3.10.



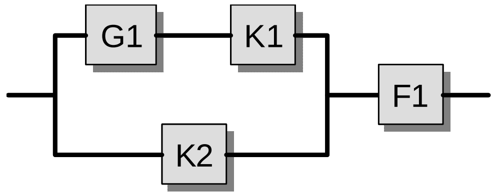
Calculation of the probability of failure

The probability of undesired disabling of the guard locking device/safety function "no disabling of guard locking at speeds greater than zero" (refer also to the safety-related block diagram) is first calculated.

- $MTTF_d$: for K1 and K2, the B_{10d} value is 400,000 cycles [S]. At 240 working days, 8 working hours and a cycle time of 10 minutes, n_{op} is 11,520 cycles per year and the $MTTF_d$ is 347 years for these components. For the electronic part of the switch-on delay in K2, an $MTTF_d$ of 1,000 years is assumed [E]. K2 thus has an overall $MTTF_d$ of 257 years. No manufacturer's figure is available for G1; an $MTTF_d$ of 30 years is assumed [E]. These values produce a symmetrized $MTTF_d$ per channel of 70 years.
- DC_{avg}: owing to the mechanical linking of the contacts, faulty states of K1 or K2 lead to sustained failure of the unlocking of the guard locking facility or of the motor energy. As a result, fault detection is provided by the process and a *DC* of 99% is assumed. A drift in the switching threshold of G1 can be detected by the process. A *DC* of 60% is therefore assumed. No fault detection is provided for failure of the switch-on delay of K2. This results in a DC_{avg} of 64%.
- Adequate measures against common cause failure (70 points): separation (15), overvoltage protection etc. (15), use of well-tried components (5) and environmental conditions (25 + 10)
- Together with fault exclusion for the further elements of the guard locking device (see above), the combination of the control elements corresponds to Category 3 with a high $MTTF_d$ per channel (70 years) and low DC_{avg} (64%). This results in an average probability of dangerous failure of 1.62×10^{-7} per hour. This corresponds to PL d.

Calculation of the probability for the safety function "prevention of unexpected start-up from rest whilst the safety guard is open" yields the following result.

- $MTTF_d$: for the position switch B1, a B_{10d} value of 20,000,000 cycles [S] is assumed owing to its direct opening action. At the assumed n_{op} value of 11,520 cycles per year indicated above, the associated $MTTF_d$ value is 17,361 years. A B_{10d} value of 100,000 cycles [E] is assumed for the position switch B2 (see also Table D.2); the associated $MTTF_d$ value is 86 years. For Q1 and Q2, the B_{10d} value is 400,000 cycles [S]. The same n_{op} produces an $MTTF_d$ of 347 years for each component. These values produce a symmetrized $MTTF_d$ per channel of 85 years.



- DC_{avg}: at the assumed high switching frequency, faulty states on all elements are detected with a *DC* in each case of 99%, e.g. by fault detection via the process. This leads to a DC_{avg} also of 99%.
- Adequate measures against common cause failure (70 points): see above
- The combination of the control elements corresponds to Category 4 with a high $MTTF_d$ per channel (85 years) and high DC_{avg} (99%). This results in an average probability of dangerous failure of 2.93×10^{-8} per hour. This corresponds to PL e. PL_r d is thus surpassed, which with the required two-channel design of the hardware with few components, the use of B_{10d} values in accordance with the standard, a *DC* of “high” and a “moderate” switching frequency will virtually always be the case.
- The wearing element B2 should be replaced approximately every eight years (T_{10d}).

More detailed references

- *Reudenbach, R.*: Maßnahmen gegen das Umgehen von Verriegelungseinrichtungen an Schutztüren. Die BG (2003) No. 7, pp. 275-281. www.diebg.info/download/reudenbach.pdf
- *Apfeld, R.; Huelke, M.; Lüken, K.; Schaefer, M.* et al.: Manipulation von Schutzeinrichtungen an Maschinen. HVBG-Report. Ed.: Hauptverband der gewerblichen Berufsgenossenschaften, Sankt Augustin 2006. www.dguv.de/bgia, Webcode d6303
- Grundsätze für die Prüfung und Zertifizierung von Verriegelungseinrichtungen mit elektromagnetischen Zuhaltungen GS-ET-19. Ed.: Fachausschuss Elektrotechnik, Cologne 2004. www.dguv.de, Webcode d14884
- Berufsgenossenschaftliche Information BGI 575: Merkblatt für die Auswahl und Anbringung elektromechanischer Verriegelungseinrichtungen für Sicherheitsfunktionen. Carl Heymanns, Cologne 2003
- EN 1088: Safety of machinery – Interlocking devices associated with guards – Principles for design and selection (12.95).
- EN 1088/A1: Safety of machinery – Interlocking devices associated with guards – Principles for design and selection (04.07)
- EN 13906-1: Cylindrical helical springs made from round wire and bar – Calculation and design – Part 1: Compression springs (04.02)

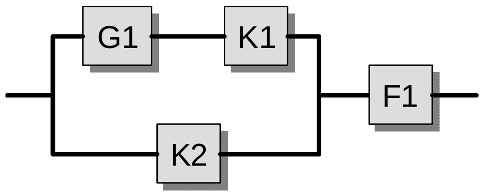


Figure 8.35:
Determining of the PL by means of SISTEMA