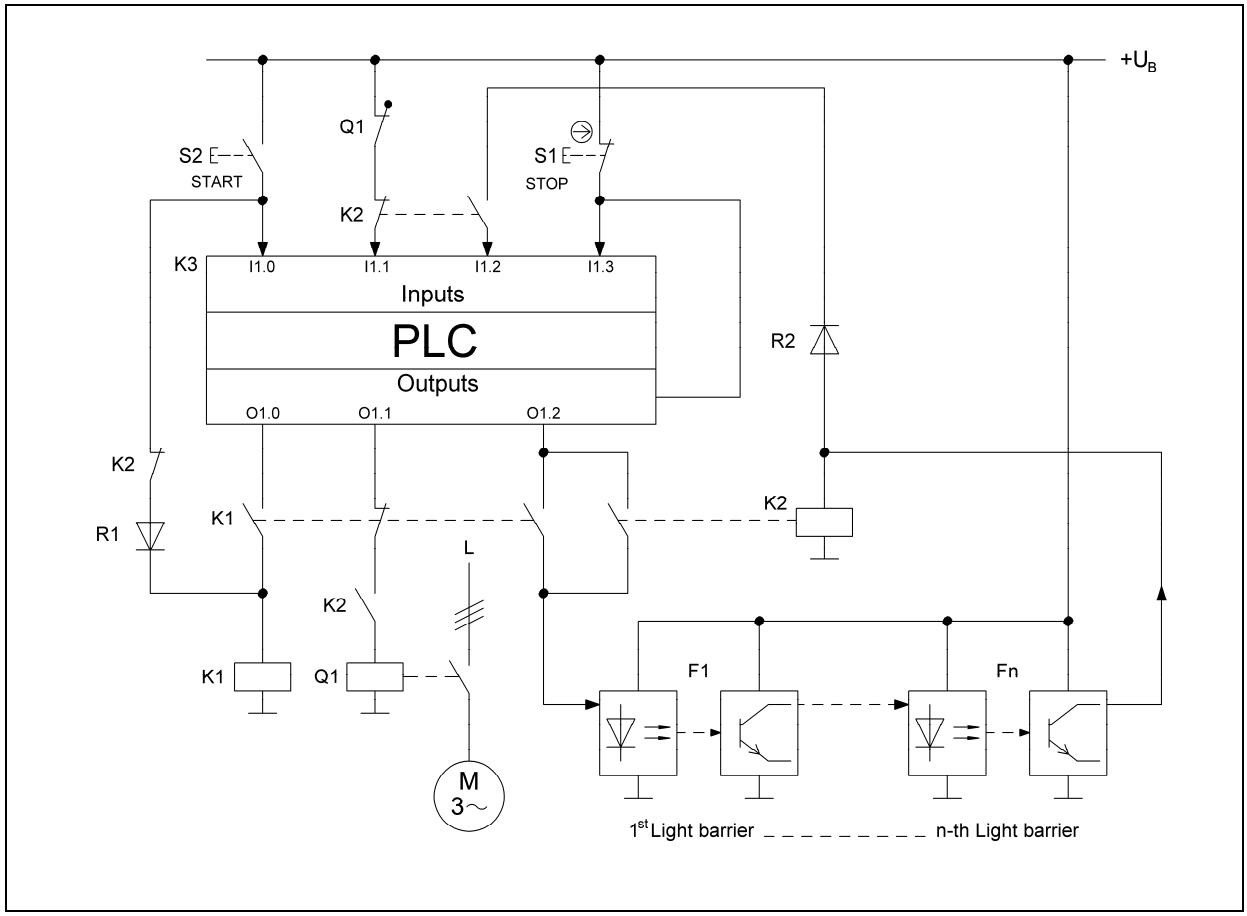
8.2.9 Tested light barriers – Category 2 – PL c with downstream Category 1 output signal switching device (Example 9)

Figure 8.17:
Testing of light barriers with a standard PLC

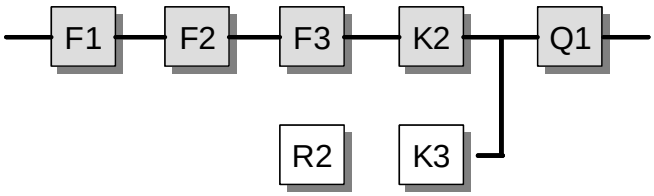


Safety function

- Safety-related stop function, initiated by a protective device: when the light beam is interrupted, a hazardous movement is halted (STO – safe torque off).

Functional description

- Interruption of the light beam of the *n* cascaded light barriers F1 to Fn triggers a de-energization command both by relays, by de-energization of the contactor relay K2, and via the PLC output (O1.1) of the test channel. The hazardous movement is then halted by means of the contactor Q1.
- The light barriers are tested before each start of the hazardous movement following pressing of the start button S2. For this purpose, PLC output O1.2 de-energizes the light barrier transmitter in response to a software command. The reaction of the receiver (K2 drops out again) is monitored on PLC inputs I1.1 and I1.2. Provided the behaviour is free of faults, K2 seals in via O1.2, and

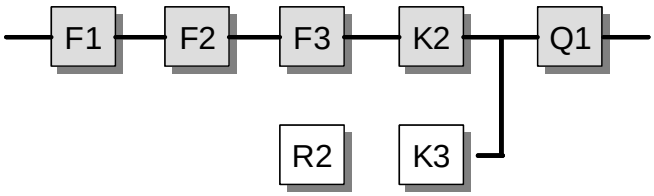


the hazardous movement can be initiated by the releasing of S2. K1 is de-energized via O1.0, and the main contactor Q1 actuated via O1.1.

- Should a fault in a light barrier or in K2 be detected by the test, the outputs O1.1 and O1.2 are deactivated, and an actuating signal is no longer applied to the main contactor Q1.
- In the event of global failure of the PLC (output O1.0 at low potential, outputs O1.1 and O1.2 at high potential), interruption of a light beam results in de-energization of K2, independently of the PLC. In order to ensure this independence, the light barrier outputs are decoupled from the PLC by the decoupling diode R2. Under unfavourable circumstances, the light barriers can be re-activated by K2 by actuation of the start button, and the main contactor Q1 thus actuated. In this case the test equipment (only) would have failed. Failure of the test equipment is detected owing to the probability of a functionally defective process under these circumstances.
- During the test, actuation of Q1 by K1 and O1.1 is blocked.

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.
- Special light barriers with adequate optical characteristics (aperture angle, extraneous light immunity, etc.) to IEC 61496-2 are employed.
- Several light barriers can be cascaded and monitored by only two PLC inputs and a relay or contactor relay.
- The contactor relays K1 and K2 possess mechanically linked contact elements in accordance with IEC 60947-5-1, Annex L. The contactor Q1 possesses a mirror contact in accordance with IEC 60947-4-1, Annex F.
- The standard components F1 to Fn and K3 are employed in accordance with the instructions in Section 6.3.10.
- The software (SRASW) is programmed in accordance with the requirements for PL b (downgraded owing to diversity) and the instructions in Section 6.3.
- The start button S2 must be located outside the hazardous area and at a point from which the hazardous area/danger point is visible.
- The number, arrangement and height of the light beams must comply with EN 999 and IEC 62046.



- Should an arrangement for the safeguarding of hazardous areas permit stepping behind the sensing field, further measures are required, such as a restart interlock. The start button S2 can be used for this purpose. To this end, the PLC K3 compares the duration for which the button is pressed with maximum and minimum values. Only if the conditions are met is a start command assumed to be valid.

Remarks

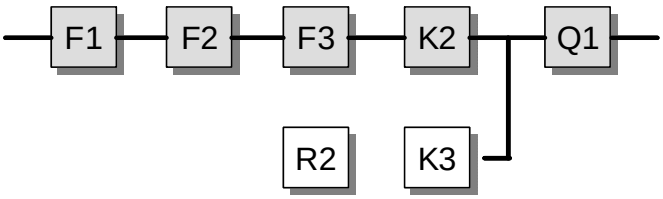
- The example is intended for use in applications with an infrequent demand upon the safety function. This enables the requirement of the designated architecture for Category 2 to be satisfied, i.e. “testing much more frequent than the demand upon the safety function” (cf. Annex G).
- Following triggering of a stop, the light barriers remain deactivated until the next start. This enables a hazardous area, for example, to be entered without this being “registered” by the circuit. The behaviour can be modified by corresponding adaptation of the circuit.

Calculation of the probability of failure

- For the sake of example, three light barriers F1 to F3 are considered for calculation of the probability of failure. Safeguarding of a second hazardous zone constitutes a further safety function for which calculation is performed separately.
- For calculation of the probability of failure, the overall system is divided into two subsystems, “light barriers” and “main contactor” (Q1).

For the “light barriers” subsystem:

- F1, F2, F3 and K2 constitute the functional path of the Category 2 circuit structure; the PLC K3 (including decoupling diode R2) constitutes the test equipment. S2 and K1 have the function of activating testing of the light barrier, and are not involved in the calculation of the probability of failure.
- $MTTF_d$: an $MTTF_d$ of 100 years [E] is assumed for each of F1 to F3. The B_{10d} value for K2 is 20,000,000 cycles [S]. At 240 working days, 16 working hours and a cycle time of 180 seconds, n_{op} is 76,800 cycles per year. Testing as described above doubles this value, to an n_{op} of 153,600 cycles per year with an $MTTF_d$ of 1,302 years for K2. These values yield an $MTTF_d$ of 32 years (“high”) for the functional channel. An $MTTF_d$ of 50 years [E] is assumed for K3. In comparison, the $MTTF_d$ value of 228,311 years [S] for the decoupling diode R2 is irrelevant.



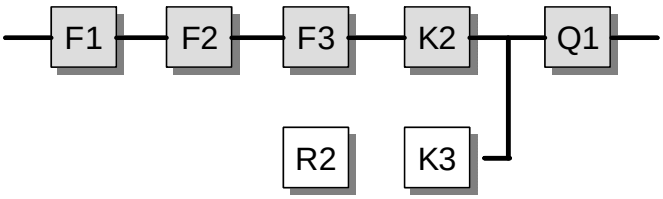
- DC_{avg}: the DC of 60% for F1 to F3 is attributable to the function test as described. The *DC* of 99% for K2 is derived from direct monitoring in K3 with the aid of mechanically linked contact elements. The averaging formula for DC_{avg} returns a result of 61.0% (“low”).
- Adequate measures against common cause failure (85 points): separation (15), diversity (20), overvoltage protection etc. (15) and environmental conditions (25 + 10)
- The combination of the control elements in the “light barriers” subsystem corresponds to Category 2 with a high $MTTF_d$ per channel (32.5 years) and low DC_{avg} (61.0%). This results in an average probability of dangerous failure of 1.85×10^{-6} per hour.

The following assumptions are made for the “main contactor” subsystem:

- B_{10d} = 2,000,000 cycles [S] with a n_{op} of 76,800 cycles per year. This leads to an $MTTF_d$ of 260.4 years, which in accordance with the standard is capped to 100 years. The structure corresponds to Category 1; DC_{avg} and common cause failures are not therefore relevant. The resulting average probability of dangerous failure is 1.14×10^{-6} per hour.
- Addition of the average probability of dangerous failure of the two subsystems results in a value of 3.0×10^{-6} per hour. This corresponds to PL c.
- If it is anticipated that a demand will be made upon the safety function more frequently than assumed for the Category 2 designated architecture (the ratio is lower than 100 : 1, i.e. more frequently than once every 5 hours), this can be considered in accordance with Annex G down to a ratio of 25 : 1 with a penalty of 10%. In the case considered here with three light barriers, the “light barriers” subsystem still attains a probability of failure of 2.04×10^{-6} per hour. The overall average probability of dangerous failure of 3.18×10^{-6} per hour only attains PL b, however. For PL c to be attained, the number of light barriers would for example have to be reduced, or components with a higher $MTTF_d$ employed.

More detailed references

- *Grigulewitsch, W.; Reinert, D.*: Lichtschranken mit Testung. In: BGIA-Handbuch Sicherheit und Gesundheitsschutz am Arbeitsplatz. Kennzahl 330 228. 22th suppl. V/94. Ed.: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin, 1985 – loose-leaf ed. www.bgia-handbuchdigital.de/330228
- EN 61496-1: Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests (05.04)



- IEC 61496-2: Safety of machinery – Electro-sensitive protective equipment – Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs) (04.06)
- IEC 62046: Safety of machinery – Application of protective equipment to detect the presence of persons (draft standard IEC 44/501/CD:2005)
- EN 999: Safety of machinery – The positioning of protective equipment in respect of approach speeds of parts of the human body (10.98)

Figure 8.18:
Determining of the PL by means of SISTEMA