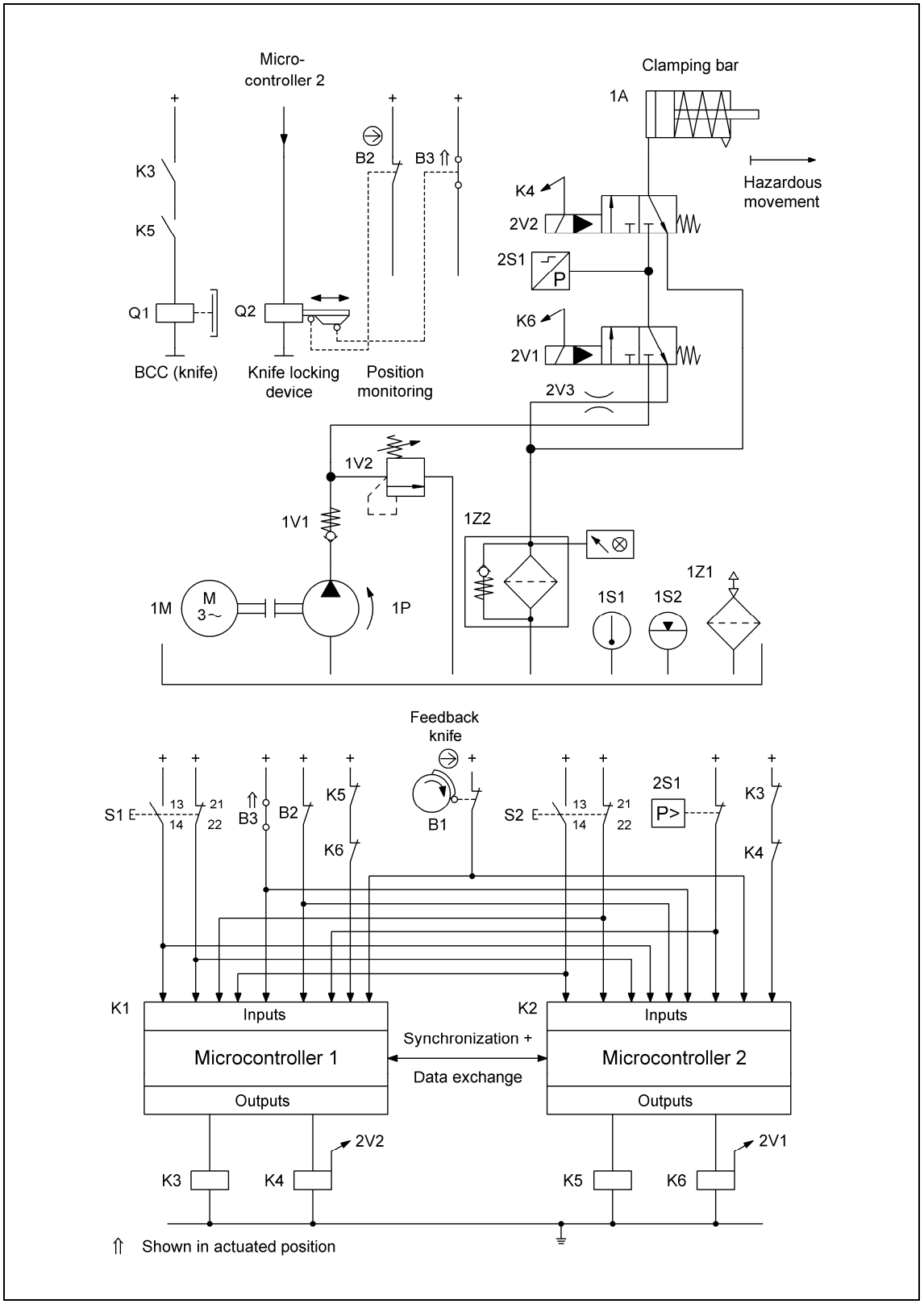
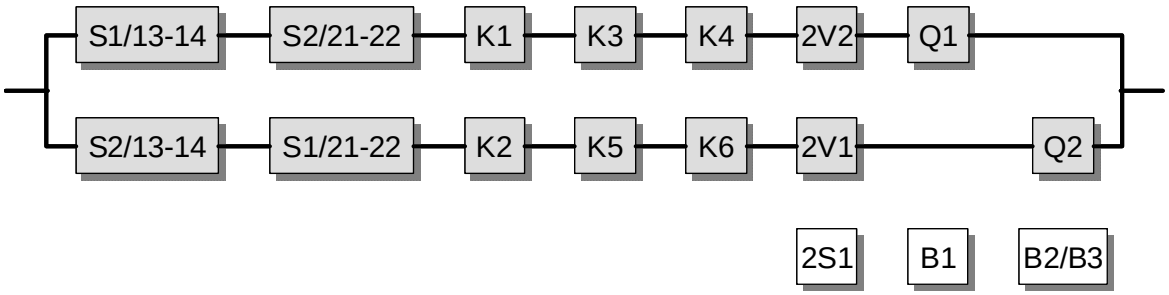
8.2.37 Paper-cutting guillotine with programmable electronic logic control – Category 4 – PL e (Example 37)

Figure 8.62:
Actuation of an electric knife drive and a hydraulic clamping bar



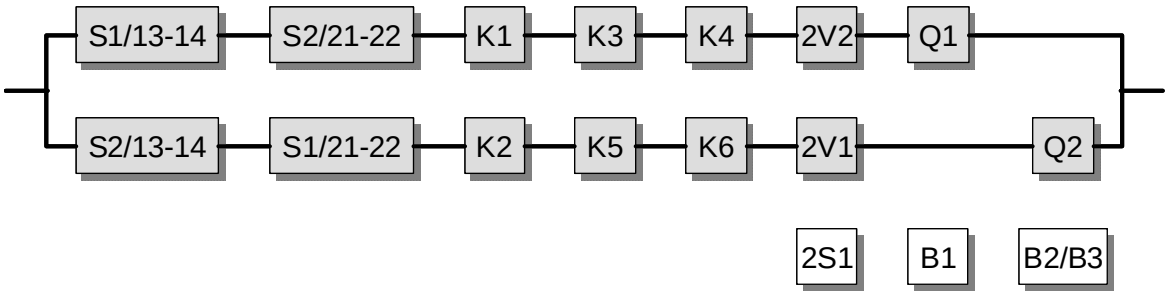


Safety function

- Controlled location of a single operator's hands outside the hazardous area during the press and cutting movement: when at least one of the two push-buttons S1/S2 is released, enabling is cancelled and remains blocked until both pushbuttons are released and pressed again synchronously.

Functional description

- Actuation of the two-hand control (THC) S1 and S2 initiates the hazardous movements (processing cycle) of the clamping bar (hydraulic) 1A and of the knife (electromechanical). If, during this cycle, either of the pushbuttons S1 or S2 is released or a signal change occurs in the peripheral system of the machine (e.g. light curtain, not shown on the circuit diagram) which is not expected by the control system, the cycle is halted and the machine remains in this safe state. Owing to their immediate physical proximity to each other, the knife and the clamping bar constitute a common hazardous zone. The hazard occurs cyclically. The knife is driven by an eccentric drive that receives its energy from a flywheel mass which is in constant motion. The drive is not shown explicitly. The clamping bar is driven linearly by a hydraulic arrangement with has a pump connected to the drive of the flywheel mass.
- When pushbuttons S1/S2 (THC) are pushed, the signal change is fed to the two microcontrollers K1 and K2. Provided these signals satisfy the requirements for simultaneity in accordance with the standard (EN 574, Type III C) and all peripheral signals satisfy the condition for a start, K1 and K2 set the outputs for a valid cut request. Each microcontroller monitors both hazardous movements through the contactor relays K3 to K6. The closing movement of the clamping bar 1A can be prevented by the two hydraulic valves 2V1 and 2V2. Actuation of the brake/clutch combination (BCC) Q1 can be prevented via K3 and K5. A suitably dimensioned mechanical knife locking device Q2 must also be enabled cyclically by K2. Should faults be detected in Q1, the knife cycle can therefore be prevented in the following cycle at the latest.
- Faults in the switches S1/S2 or in the contactor relays with mechanically linked positively operating readback contacts K3 to K6 are detected in the microcontrollers by cross-checking. The functioning of 2V1/2V2 is monitored by means of the pressure switch 2S1. Since the microcontrollers perform self-tests in addition in the background during operation, internal faults and faults in the peripherals can be detected here in time.



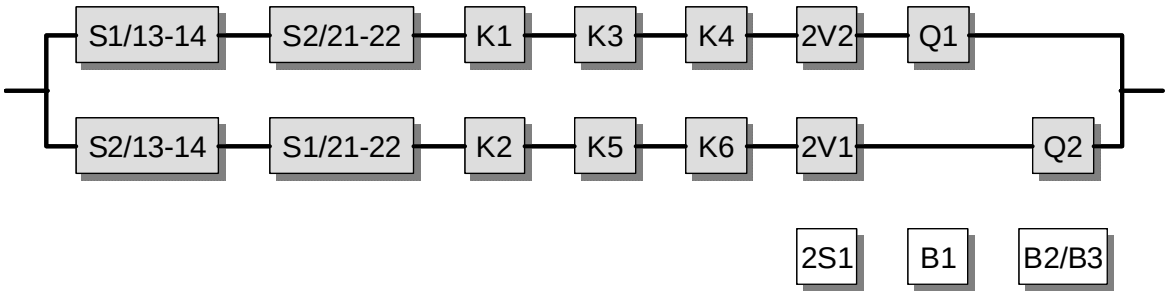
- All machine states are monitored and controlled by both microcontrollers. The cyclical nature of the cut operation causes all system states to be cycled through and compared with each other. Faults and deviations from defined intermediate states cause the machine to be halted at the latest upon completion of the cycle. This method is implied in the diagram by “feedback signal knife” B1 and “position monitoring” B2/B3 of “knife locking device” Q2.
- Brake wear is monitored with the aid of the position switch B1. B1 is actuated and a further cut prevented by the control system in response to the slightest increase in the overrun.

Design features

- Basic and well-tried safety principles are observed and the requirements of Category B are met. Protective circuits as described in the initial paragraphs of Chapter 8 are implemented.
- The actuators S1 and S2 of the two-hand control satisfy IEC 60947-5-1.
- B1 and B2 are position switches with direct opening action to IEC 60947-5-1, Annex K.
- K3 to K6 possess mechanically linked contact elements to IEC 60947-5-1, Annex L.
- The supply conductors to the position switches are laid either separately or with protection against mechanical damage.
- The software of the homogeneously redundant microprocessor structure satisfies the requirements of IEC 61508-3, Section 7 for SIL 3.
- A fault exclusion applies for the fault “complete failure of the brake/clutch combination”, i.e. failure to disengage when the cut enable is cancelled following initiation of a cut. The reasoning for this fault exclusion is based upon many years of experience and the design features of the brake/clutch combination with the possibility of early detection of brake wear.
- The components B1 and B2/B3 are required for implementation of the measures required in EN 1010-3 for stopping and overrun of the knife.

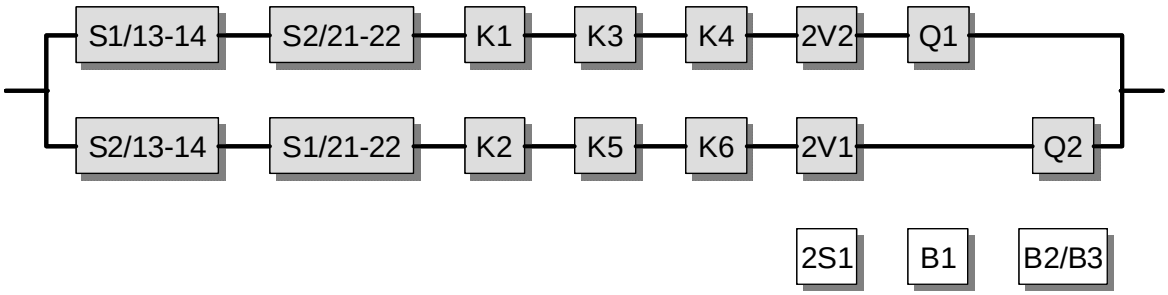
Calculation of the probability of failure

- The designated architecture for Category 4 for actuation of the knife drive and the clamping bar is implemented by two independent channels as described.



Since the channels are virtually identical in their arrangement and are calculated with the use of identical numerical data, symmetrization is not required. For the sake of simplification, only single-channel actuation of Q1 is assumed. The probability of failure is therefore slightly lower in practice than that calculated.

- Since S1 and S2 must trigger shut-off independently of each other when released, they are connected logically in series. For this purpose, one make contact 13-14 and one break contact 21-22 for each pushbutton were assigned to a control channel. The safety-related block diagram differs substantially in this respect from the functional circuit diagram. The B_{10d} value for each individual contact is employed, constituting an estimation erring on the safe side.
- $MTTF_d$: at 240 working days, 8 working hours and a cycle time of 60 seconds, n_{op} is 115,200 switching operations per year. Owing to the defined control current (low load; the mechanical lifetime of the contacts is the determining factor), B_{10d} values of 2,000,000 switching operations [M] are assumed for S1 and for S2, and therefore an $MTTF_d$ of 173 years. An $MTTF_d$ of 878 years [D] is stated for the microcontroller including peripherals, in accordance with SN 29500-2. At low load, a B_{10d} of 20,000,000 switching operations [S] and thus an $MTTF_d$ of 1,736 years applies for the contactor relays K3 to K6. The $MTTF_d$ value of 607 years for the brake/clutch combination Q1 is calculated from the B_{10d} value of 7,000,000 cycles [E]. The same value is assumed for the knife locking device Q2 in the second channel. The values for the two directional control valves 2V1 and 2V2 are 150 years [S]. These values result in an $MTTF_d$ for one channel of 45.2 years (“high”).
- DC_{avg}: the *DC* of 99% for S1/S2 is based upon the cross-checking of input signals without dynamic test, with frequent signal changes. The *DC* of 90% for K1/K2 is derived from self-tests performed by software and the dynamic cross-checking of data with expectations regarding timing. The *DC* of 99% for K3 to K6 is derived from plausibility testing by means of mechanically linked contacts. For 2V1/2V2, the *DC* is 99% owing to indirect and direct electrical monitoring of the pressure with frequent signal changes. Wear in the clutch leads to a change in cutting behaviour. This behaviour is monitored by instruments. A *DC* of 99% is therefore assumed for Q1. Failure of Q2 is detected immediately owing to cyclical actuation and the monitoring elements B1 and B3. This is the reasoning for a *DC* of 99%. These values result in a DC_{avg} of 98.5% (within the tolerance of “high”).
- Adequate measures against common cause failure (65 points): separation (15), overvoltage protection etc. (15) and environmental conditions (25 + 10)



- For Category 4, the average probability of dangerous failure is 6.47 × 10^{-8} per hour. This corresponds to PL e.
- In consideration of the estimation erring on the safe side described above, a value of over 17 years (T_{10d}) is produced for the designated replacement of the wearing elements S1 and S2.

More detailed references

- EN 1010-3: Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 3: Cutting machines (07.02)
- EN 574: Safety of machinery – Two-hand control devices – Functional aspects; principles for design (11.96)
- IEC 60947-5-1: Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices (11.03)

Figure 8.63:
Determining of the PL by means of SISTEMA