

Safety Lock-Out on AC and DC Drives

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INTRODUCTION

Long products mills are prone to a high level of product changeover. Each product changeover may involve disabling or completely changing a stand. International safety standards demand that each person involved in the process of changing the stand apply an effective and individual lock on the Drive or Drives of the stands that will be intervened. This regulation implies exposing not necessarily qualified personnel to electrical panels, with their inherent hazards. Additionally, qualified electrical personnel may be inevitably exposed to highly caloric energy in each operation of the connection switch. This article describes methods used to mitigate the exposure to risk of electrical accident for both mechanical and electrical personnel, as well as improving productivity by minimizing downtime and increasing the lifetime of Drives, by reducing maneuvers.

Lock-Out System for AC Drives

General Principles

The most common type of drive currently available on the market is the AC drive with pulse width modulation (PWM). The power structure of the drive can be divided into three different sections: a converter, a filter, and an inverter.

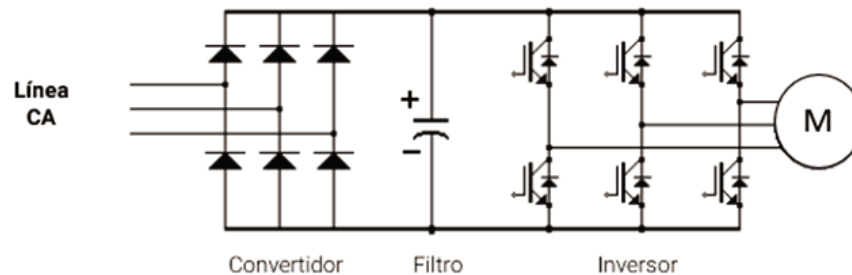


Fig.1 Power structure of an AC drive

Since the inverter section requires a DC power supply, a converter is necessary. In most cases, full wave diode rectifiers are used, although in some cases thyristors are used instead of diodes. The second stage consists of a filter made of a capacitor bank necessary to create a stable and smooth DC supply, required for running the IGBT inverter.

The final stage is the inverter section. This section uses high-speed transistors as switches to apply a "Pulse Width Modulation" or PWM waveform to the motor. DC voltage can be applied in pulse width variation to achieve a motor current that approximates a sine wave. Varying the pulse width in proportion to the frequency creates the volts per Hertz ratio that meets the motor design and allows the rated torque to be produced at base speed or lower, without excessive current.

If the IGBTs are not turned on, no current or torque can be produced in the motor and it behaves as if there is an open contactor in the motor supply.

Lock-Out Method for AC Drives

The AC drive has a functional safety circuit by which the power supply to the motor can be switched off. The inverter has two input ports (UV1 and UV2) that receive the safety stop signals with their individual feedback (UV1_F and UV2_F). The drive trigger signals can be disabled by means of two independent signals, by using two separate channels in its internal safety circuit; that is to say, the drive can be stopped even if one channel of the safety circuit is damaged.

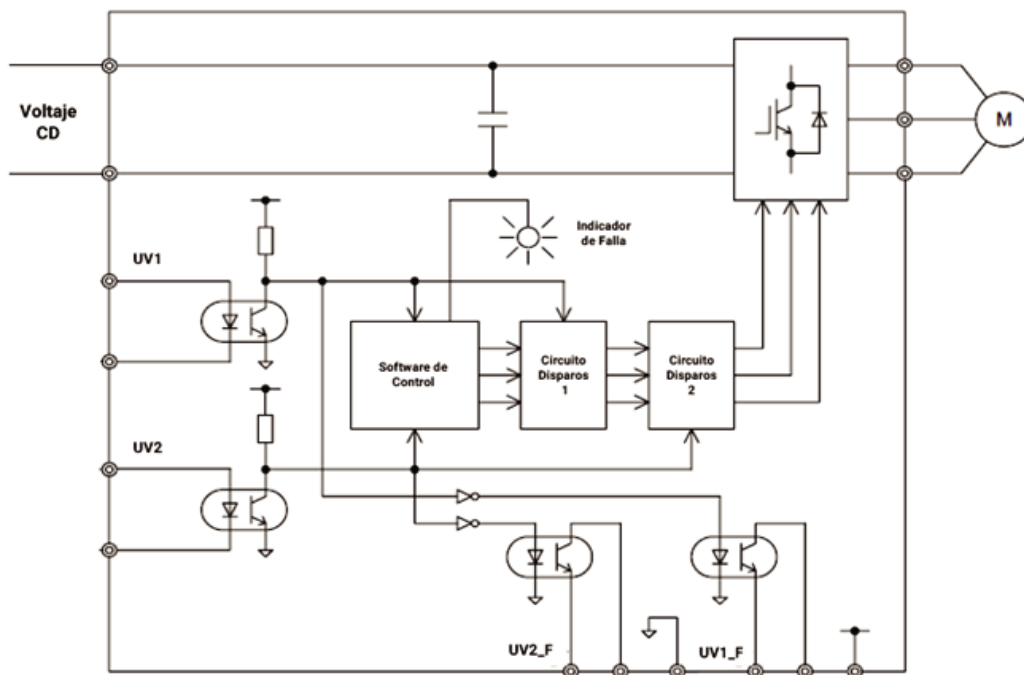


Fig. 2 Composition of the internal functional safety circuit of an AC inverter.

In addition to the internal functional safety circuit of the drive, a contactor (equipped with a “failsafe” interface) is added to the inverter output to disable the machinery by a separate route. The control of the contactor is linked to the internal safety functional circuit of the inverter. That is, if the internal functional circuit of the drive loses one of the UV1 or UV2 inputs or its corresponding feedback, the contactor opens immediately. In addition, the safety module opens a contact connected in series with the internal control circuit of the contactor. This ensures that the motor power will be disabled.

Automatic diagnosis of the functional safety system is carried out with a safety module. The diagnosis is provided by finding the status correspondence between the safety input and output signals (feedback). The equipment that provides the diagnosis must also be functional safety equipment (PLC or Safety Relay).

The image in figure 3 shows the functional safety system circuit for lock-out an AC drive.

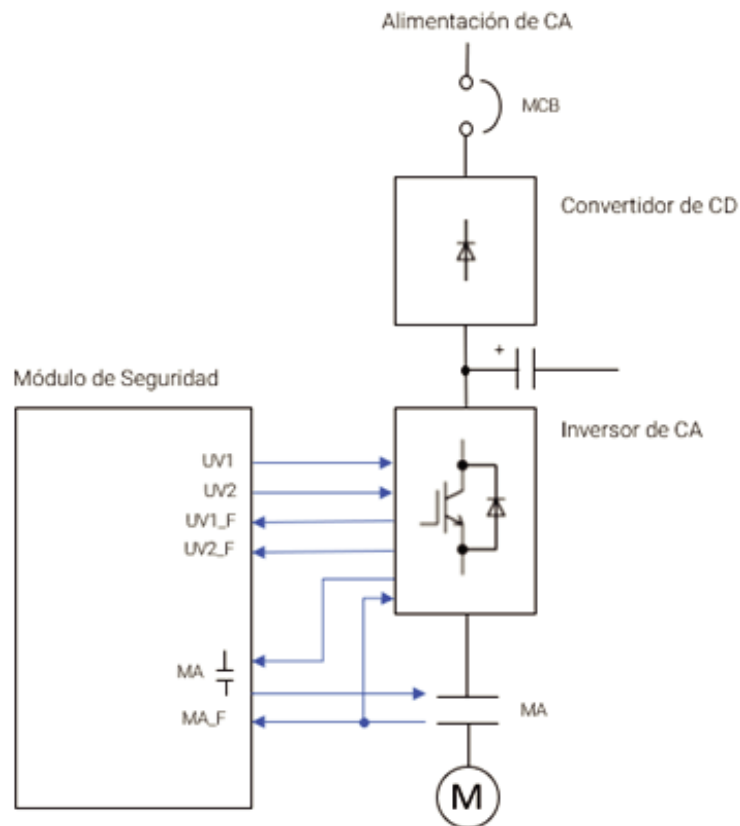


Fig. 3 Lock-Out safety system circuit for an AC inverter.

In case of connecting several AC drives to a common converter, the lock-out system would require the same number of inputs and outputs per drive connected to the safety module.

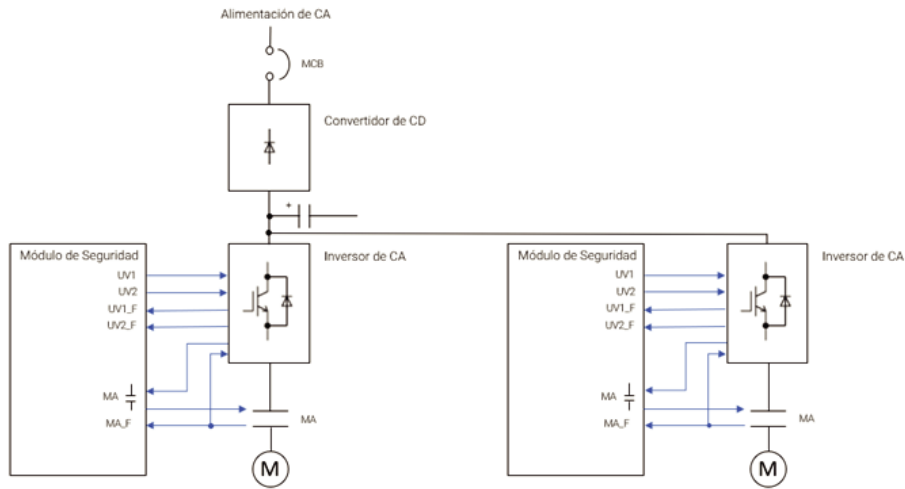


Fig. 4 Lock-Out safety system circuit for multiple AC drives.

Lock-Out System for DC Drives

The lock-out system for a DC drive varies according to the hardware used in its design, which is determined considering the application and specifications of current.

The 4 general configurations that can be considered are described below.

Case 1: DC drive with AC contactor MA at the input and thyristor field source.

This configuration is used when the input current of the converter is less than or equal to 1300Amp. The MA alternating current contactor is equipped with a "failsafe" interface.

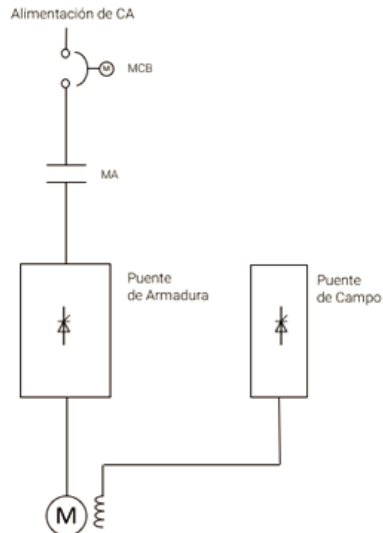


Fig. 5 DC drive configuration (Case 1)

Case 2: DC drive with AC contactor MA at the input and IGBT field source.

This configuration is used when the input current of the converter is less than or equal to 1300Amp. The armature bridge is non-regenerative and a reversible field is required.

The MA alternating current contactor is equipped with a “failsafe” interface.

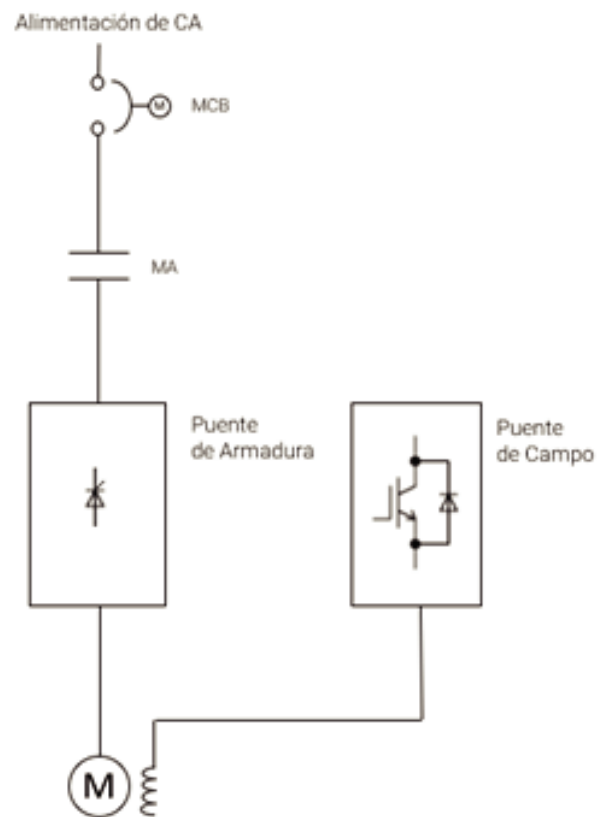


Fig. 6 DC Drive Configuration (Case 2).

Case 3: DC drive with DC contactor at the converter output and thyristor field source.

This configuration is used when the current capacity of the converter is greater than 1500Amp, due to the limitation in the current capacity of the AC contactors.

The MCB main switch can be set to low or medium voltage.

A two-pole MD direct contactor equipped with a “failsafe” interface is added, which interrupts both motor terminals.

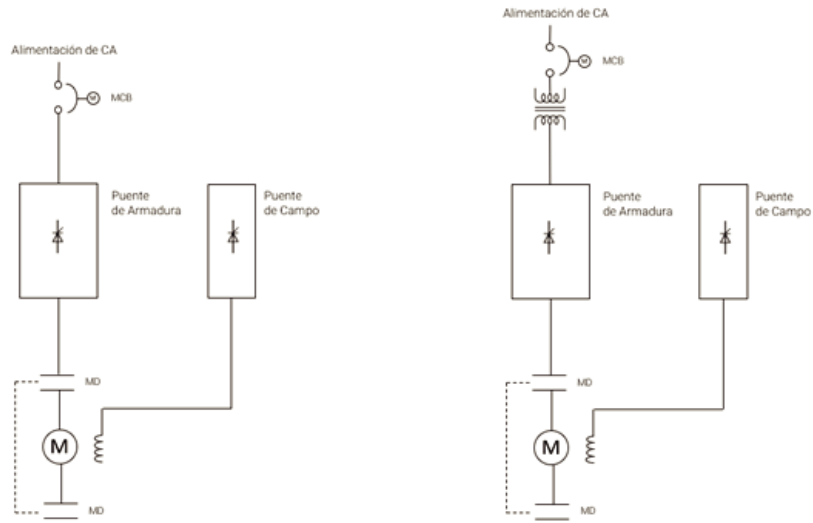


Fig. 7 DC drive configuration (Case 3).

Case 4: DC drive with DC contactor at the converter output and IGBT field source.

This configuration is used when the current capacity of the converter is greater than 1500Amp, due to the limitation in the current capacity of the AC contactors, the armature bridge is non-regenerative and a reversible field is required.

The MCB main switch can be set to low or medium voltage.

A two-pole MD direct contactor equipped with a “failsafe” interface is added, which interrupts both motor terminals.

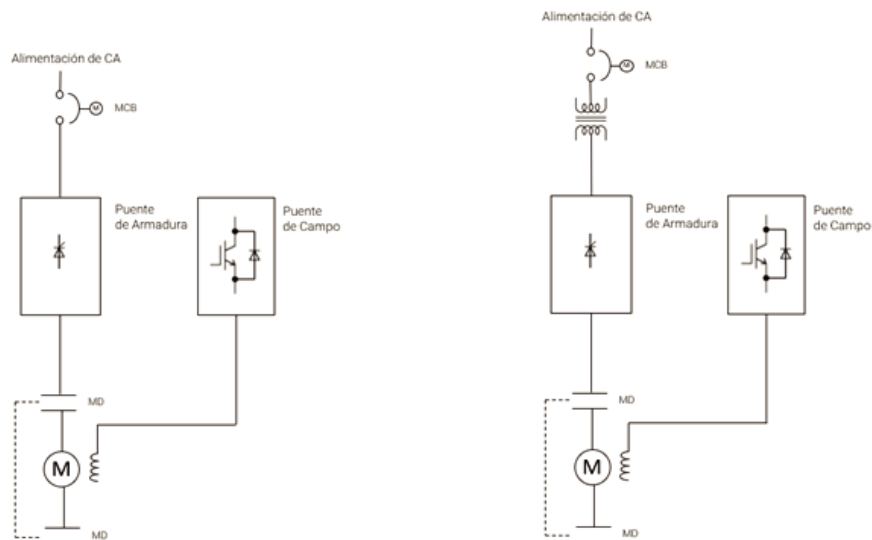


Fig. 8 DC drive configuration (Case 4).

Composition of lock-out functional circuit Case 1

Figure 9 shows the composition of the safety functional circuit for lock-out a DC drive for the configuration of case 1.

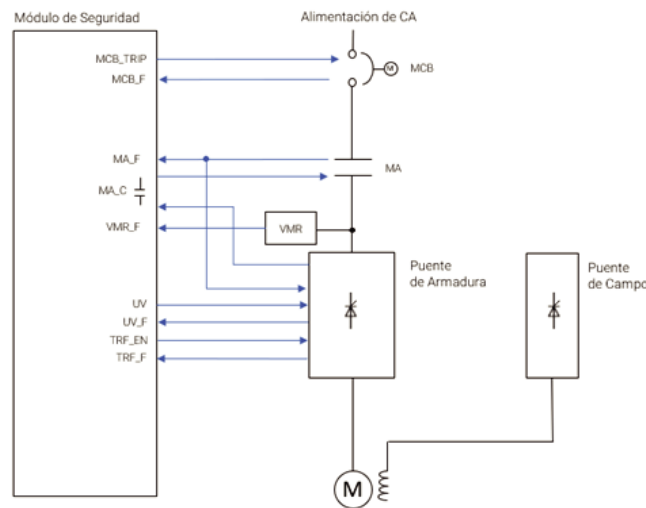


Fig. 9 Lock-out system circuit for CD drive Configuration case 1

The DC drive has a dedicated input for the emergency stop circuit (UV) which is hardware and software related to the contactor. The wired connection is made inside the I/O interface card, so this signal will open the contactor immediately. At the same time, the safety device opens a contact that is connected in series with the contactor coil. This ensures that the contactor remains open at any time. Simultaneously, the safety device removes the trigger enabling signal from the trigger card of the drive. This signal prevents the thyristors from conducting.

In addition to the double disconnection of the drive (AC contactor and trigger disablement), another level of safety is included by means of an AC voltage monitoring safety module, which constantly monitors the power supply. In case the system is locked, and voltage is detected, the main MCB switch is commanded to open.

Automatic diagnosis of the functional safety system is carried out with a safety module. The diagnosis is provided by finding the status correspondence between the safety input and output signals (feedback). The equipment that provides the diagnosis must also be functional safety equipment (PLC or Safety Relay).

Composition of lock-out functional circuit Case 2

Figure 10 shows the composition of the safety functional circuit for lock-out a DC drive for the configuration of case 2.

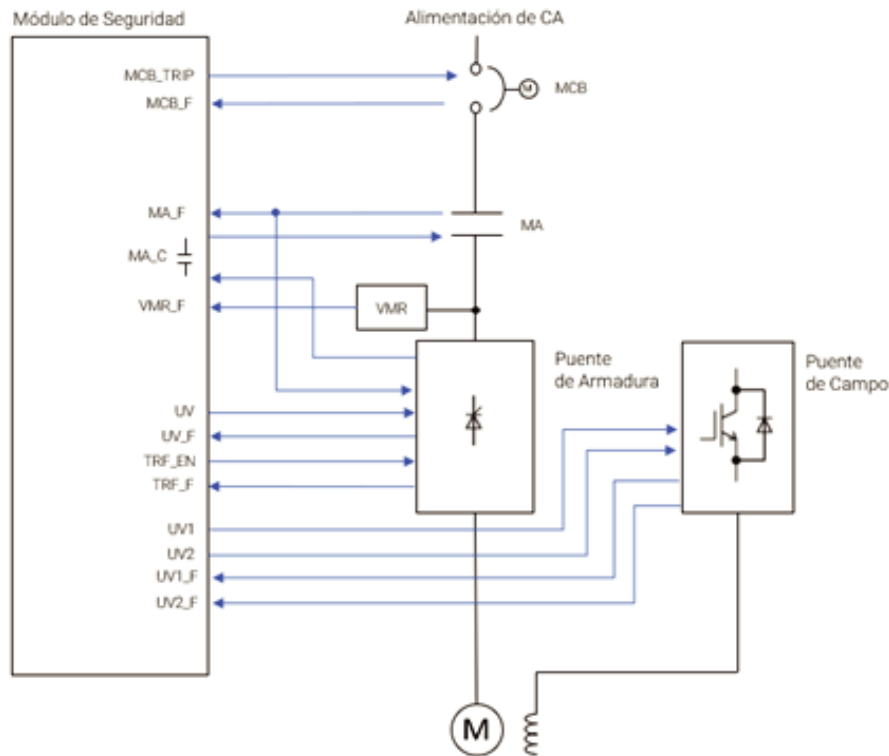


Fig. 10 Lock-out system circuit for DC drive Configuration case 2

The DC drive has a dedicated input for the emergency stop circuit (UV) which is hardware and software related to the contactor. The wired connection is made inside the I/O interface card, so this signal will open the contactor immediately. At the same time, the safety device opens a contact that is connected in series with the contactor coil. This ensures that the contactor remains open at any time. Simultaneously, the safety device removes the trigger enabling signal from the trigger card of the drive. This signal prevents the thyristors from conducting, and the field is disabled by the functional safety circuit of the IGBT field source. The field source has two input ports (UV1 and UV2) that receive the safety stop signals with their individual feedback (UV1_F and UV2_F). The field source trigger signals can be disabled by two independent signals by using two independent channels in its internal safety circuit; that is to say, the source can be disabled even if one channel of the safety circuit is damaged.

In addition to the double disconnection of the drive (AC contactor, trigger disablement and field disablement), another level of safety is included by means of an AC voltage monitoring safety module, which constantly monitors the power supply. In case the system is locked, and voltage is detected, the main MCB switch is commanded to open.

Automatic diagnosis of the functional safety system is carried out with a safety module. The diagnosis is provided by finding the status correspondence between the safety input and output signals (feedback). The equipment that provides the diagnosis must also be functional safety equipment (PLC or Safety Relay).

Composition of lock-out functional circuit Case 3

Figure 11 shows the composition of the safety functional circuit for lock-out a DC drive for the configuration of case 3.

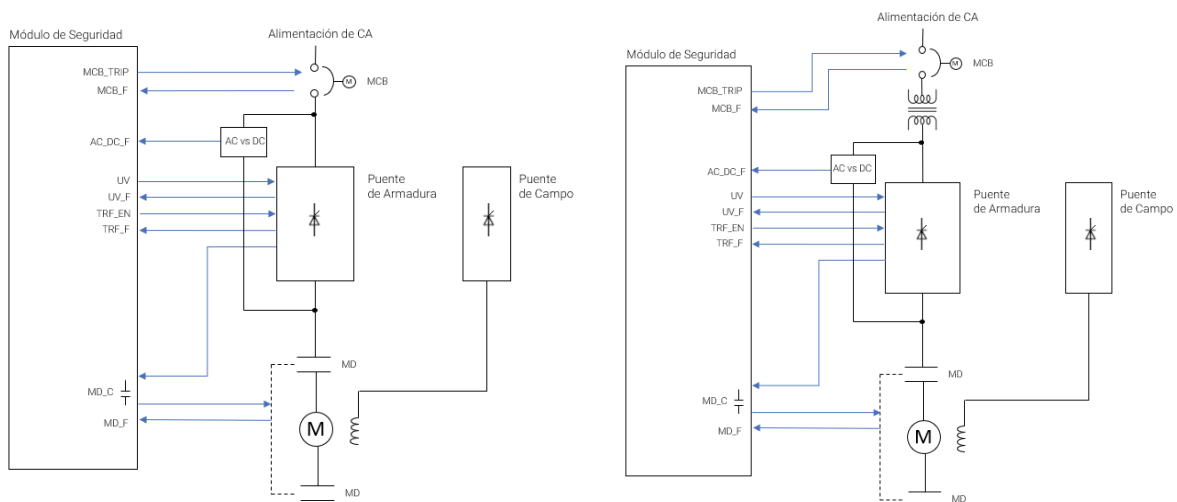


Fig. 11 Lock-out system circuit for DC drive (Case 3)

In this configuration, the DC drive has a dedicated input for the emergency stop circuit (UV) which is hardware and software related to the contactor. The wired connection is made inside the I/O interface card, so this signal will open the MD contactor immediately. At the same time, the safety device opens a contact that is connected in series with the contactor coil. This ensures that the contactor remains open at any time. Simultaneously, the safety device removes the trigger enabling signal from the trigger card of the drive. This signal prevents the thyristors from conducting.

In addition to the double disconnection of the converter (DC contactor and trigger disablement), another level of safety is included by means of an AC vs DC voltage monitoring safety module, which constantly monitors the power supply. In the event that the system is locked, and a voltage differential is detected, the main MCB switch is commanded to open.

Composition of lock-out functional circuit Case 4

Figure 12 shows the composition of the safety functional circuit for lock-out a DC drive for the configuration of case 4.

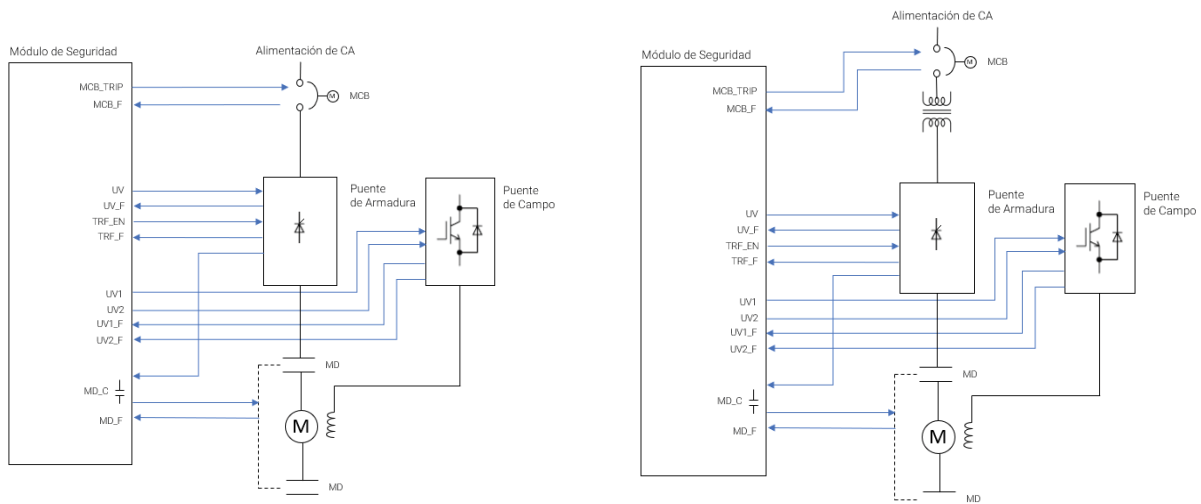


Fig. 12 Lock-out system circuit for DC converter (Case 4)

In this configuration, the DC converter has a dedicated input for the emergency stop circuit (UV) which is hardware and software related to the MD contactor. The wired connection is made inside the I/O interface card, so this signal will open the MD contactor immediately. At the same time, the safety device opens a contact that is connected in series with the contactor coil. This ensures that the contactor remains open at any time. Simultaneously, the safety device removes the trigger enabling signal from the trigger card of the drive. This signal prevents the thyristors from conducting.

In addition to the double disconnection of the converter (DC contactor and trigger disablement), another level of safety is included by disabling the field by means of the functional safety circuit of the IGBT field source. The field source has two input ports (UV1 and UV2) that receive the safety stop signals with their individual feedback (UV1_F and UV2_F). The field source trigger signals can be disabled by two independent signals by using two independent channels in its internal safety circuit; that is to say, the source can be disabled even if one channel of the safety circuit is damaged.

Example of operating console and lock-out procedure for a rolling mill

This section describes an example of lock-out procedure for a rolling mill. For this case, the drive system is made of DC drives with an AC contactor at the input of the converter and thyristor field sources (Case 1).

The conditions to carry out the lock-out are that the mill is not running and that all the procedures for clearing and stopping the motors are followed until the moment of starting the procedure.

The image in Fig. 13 shows the operation panel for lock-out the continuous rolling mill. In this case, 4 sections are considered: entry, intermediate, finishing and shears. Each section can be locked independently.

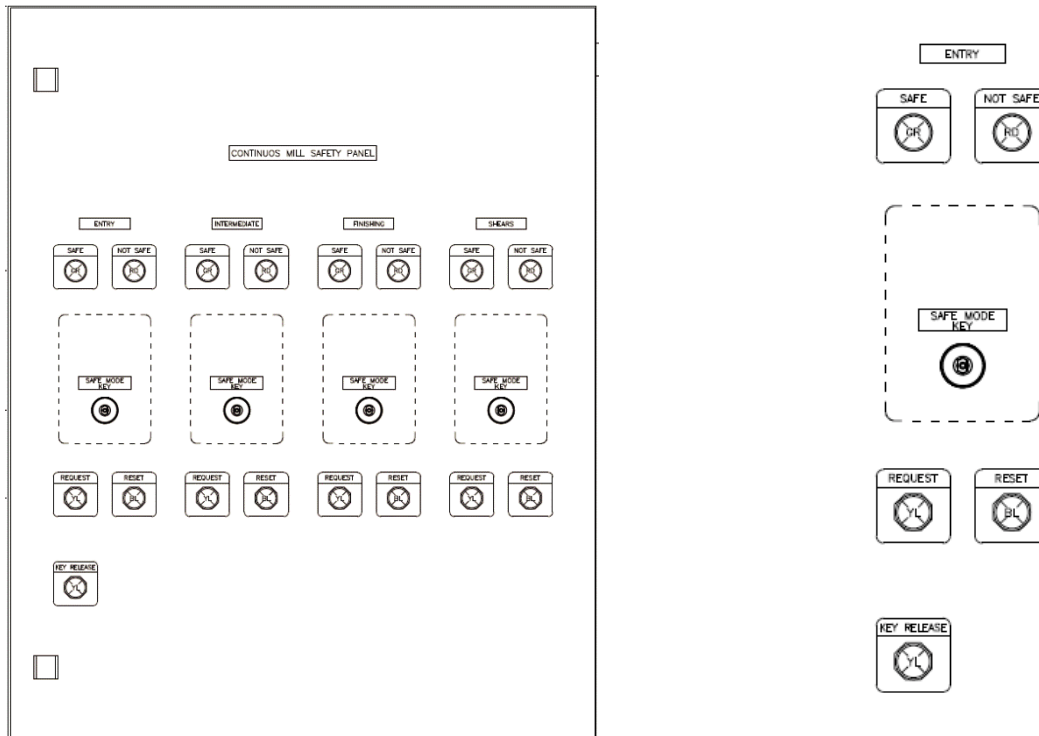


Fig. 13 Operation panel for mill lock-out

The controls are divided by section and each section has indicator lights to show the section status ("SAFE" or "NOT SAFE"). Buttons with "REQUEST", "RESET" illuminated indicators and "SAFE MODE KEY" to enable the safe mode. In addition, there is a "KEY RELEASE" button necessary to remove the safety key.

The lock-out procedure is started with a request for a safe condition by pressing the "REQUEST" button from the Lock-Out Panel. The request must be confirmed by the operator in the main pulpit. This request remains active for a certain period of time (in this case 3 minutes). During the request, the yellow indicator light of the "REQUEST" button keeps blinking. In case there is no confirmation within 3 minutes, the request is turned off. If there is confirmation, the yellow light stays on solid.

Once the safety device detects a request confirmation for a safe condition, the safety PLC commands the drive or drives to open the contactor of the selected stands. The safety relay disables the main contactor (MA), the triggers and the drive with the UV. Once there is confirmation of all the "Safety Permits", the drive is ready for a safe condition.

The safety permits monitored by the safety module are:

- Line voltage
- Disabling of armature trigger cards
- UV
- AC contactor

When all drives in the requested section are ready for a safe condition, the section is in a safe condition and the green "SAFE" indicator light is continuously on. The "NOT SAFE" indication is the reverse of the "SAFE" condition. An indication should always be on.

With the "SAFE" condition active and by pressing the "KEY RELEASE" button, the key can be turned and removed. When the "SAFE" condition is active it can only be reset by the key in the "RUN" position and the manual "RESET" of the operating station. If "RESET" is possible, the blue "RESET" indicator light blinks until the key is not in the "RUN" or "NOT SAFE" position. When the safe request is confirmed for one section, any other section can start the safe condition process upon a request from the lock-out security panel until the safe condition is reestablished for all sections (it is not necessary that the request is confirmed again).

In safe condition, safety permits are constantly monitored. If any of the monitored conditions is lost during the "SAFE" condition, the safety PLC commands to open the main switch (MCB) and the "WARNING" signal for safe condition is activated. This "WARNING" sends an alarm message on the HMI and sends a constant visual alarm to the operation panel in addition to an audible alarm with a short pulse (2 seconds). If the unsafe condition is still present after the main MCB switch is open and the short pulse is completed, a safe condition failed alarm is generated alarming the HMI and generating a constant audible and visual alarm. Both alarms can only be cleared by returning the key to the "RUN" position.

If for any reason the MCB main switch is triggered by failure, it does not close automatically when the safe condition is restored. The main MCB switch must be closed by the operator.

When the safe condition is reestablished, the stands must be safely enabled (SCR trigger enablement and the UV signal returns to running status). The drive cannot start automatically; it has to wait for the starting command.

CONCLUSIONS

For the implementation of a security lock-out system, it is necessary to consider the different types of drive (AC or DC drives) as well as the hardware configuration of each type, according to the application. Each type and configuration of drive requires the consideration of a different lock-out philosophy, but any option must comply with the international safety standards seeking to mitigate the exposure to risk of electrical accident to both mechanical and electrical personnel. If correctly implemented, improvement in productivity can be achieved by minimizing downtime and increasing the life of the drives by reducing maneuvers.