PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

NOUR BACHIR UNIVERSITY CENTER EL BAYADH

Institute of Technology

Electrical engineering Department

3RD YEAR OF BACHELOR'S DEGREE IN ELECTRICAL ENGINEERING

Electrical schematics and Electrical Switchgear

Directed by:

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Academic Year 2024/2025

Subject 1: **Electrical schematics and Electrical Switchgear**

Half-yearly hourly volume: 37h30 (Lectures: 1h30, Practical work: 1h00)

Credits: 3

Coefficient: 2

Evaluation method: Continuous assessment: 40%; Exam: 60%.

Objectives of the teaching subject:

This subject covers the design of electrical assemblies in the domestic and industrial sectors: analysis, operating principles, schematic diagrams of electrical circuits, learning about the different types of protection and control devices, and the sizing of electrical equipment for all types of application. It also enables students to put into practice the knowledge acquired during their training by creating electrical circuits and applying them to lighting and electric motor control circuits.

The course covers four chapters:

Chapter I: Electrical equipment

Chapter II: Drawing up electrical diagrams

Chapter III: Lighting circuits

Chapter IV: Three modes of electric motor control.

Contents

Chapter I: Electrical equipment

1. Switches

Definition: An electrical switch is a physical device used to control an electrical circuit, enabling or disabling the flow of current. It is symbolized in the NE standard by the letter S.

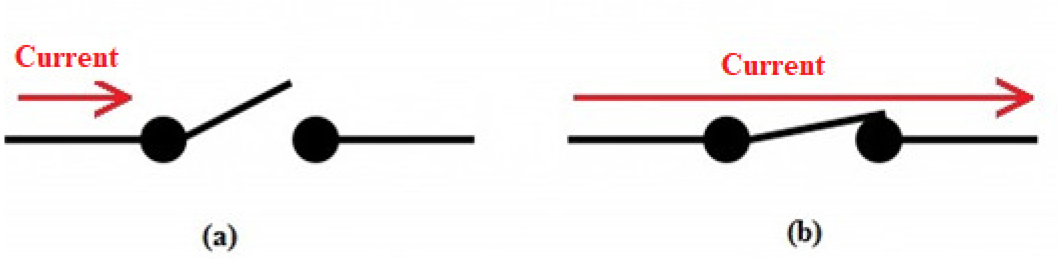


Figure I.1: Standard switch symbol: (a) open state (b)closed state

There are several types of switches:

- **Push-button switch**

The push button switch is a momentary or momentary-action device used to send an electrical impulse to open or close a circuit. Pressing a button changes the state of the contact.

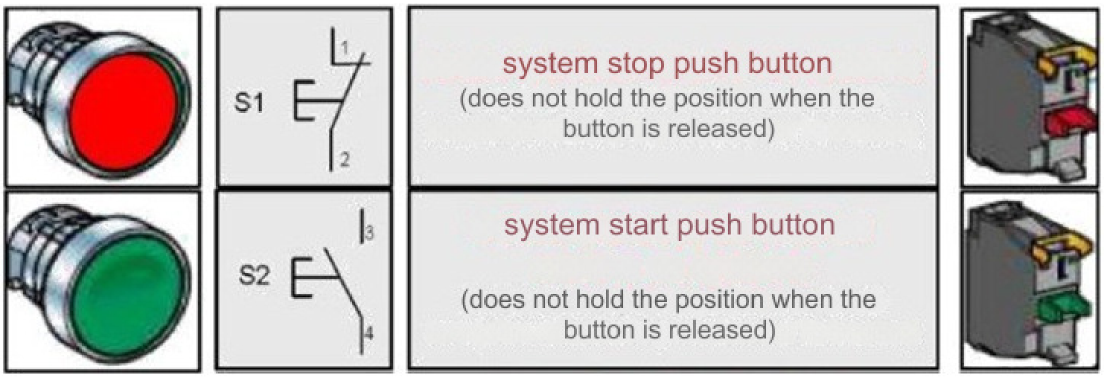


Figure I.2: Push-button states,

S1 push button initially closed,S2 push button initially open.

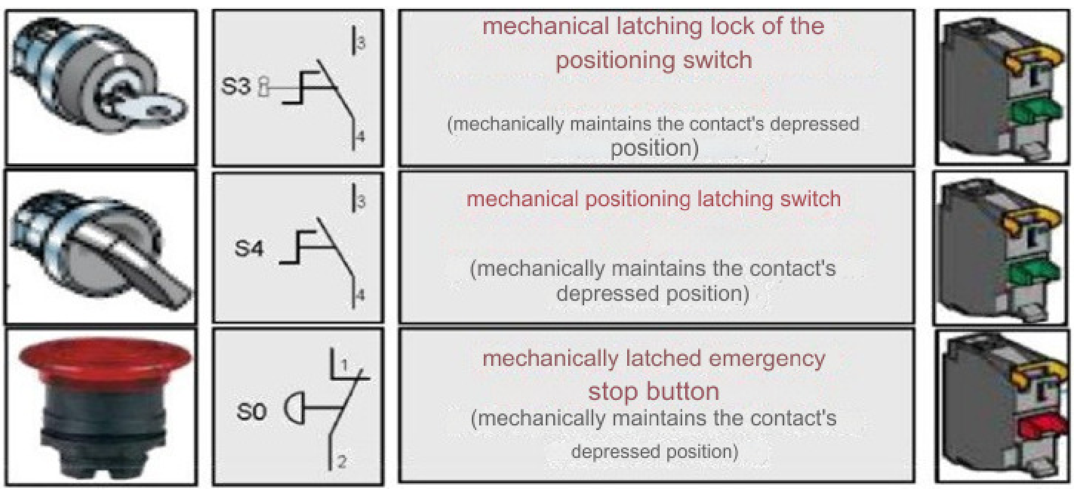


Figure I.3: Switch states,

S3 key-operated rotary switch,**S4** rotary switch and **S0** mush room-head emergency stop button.

The switches are marked in the electrical diagrams with the numbers 1 and 2 for the closed state and 3 and 4 for the open state, as shown in Figure I.4, and the operating diagram for the pushbuttons is shown in Figure I.2.

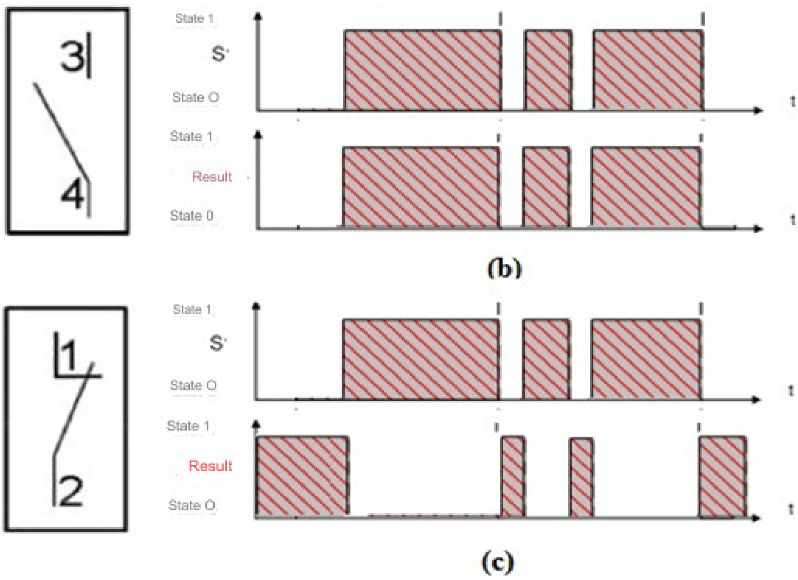


Figure I.4: Switch operating diagram

- **Lever switch**

Lever switches are among the most basic and common of electrical components. The operating lever protrudes from the front of a support, which may be a dashboard, to which the switch is frequently attached by a nut device.

Figure I.5: Lever switch

- **Rocker switch**

Toggle switches are the most common. They operate identically to toggle switches, with the toggle button simply being a flat lever. They are limited to three states, and frequently two states are used (on/off). Their position is not necessarily easy to visualize quickly, except when their ergonomic sare specifically designed, as for example in automotive equipment. This type of switch is often the most reliable, because the rocker mechanics are specifically adapted to electrical switching: by combining the work of the operator with the action of a particularly simple spring device, it ensures smooth and reliable electrical and mechanical transitions.

Figure I.6: Rocker switch

- **Slide switch**

A slide switch has the advantage of being able to offer more than three stable positions, with the added bonus of a visual position indicator. On the other hand, they are not always easy to operate, requiring a great deal of care and dexterity.

This type of switch was frequently used in domestic and professional sound equipment, where it has now been replaced by static integrated-circuit electronic switches, which are far more reliable and considerably less expensive.

Figure I.7: Slide switch

- **Rotary knob or rotary switch**

Rotary switches, frequently referred to as rotary switches, are controlled by a shaft to which a knob is attached, and which also serves as a cover plate. This type of switch can always have more stable positions than a slide switch, and can offer numerous split circuits. On some models, these two parameters can even be modified before installation.

Figure I.8: Rotary switch

- **Soft-blade switch**

A reed switch is a switch that makes or breaks an electrical connection depending on the presence or absence of a magnetic field

It usually consists of a protective glass ampoule containing a non-oxidizing atmosphere (no oxygen or water vapor) and two flexible contacts. These contacts are magnetizable and elastic, using soft iron for example. In the presence of a magnetic field, the contacts become magnetized by influence, and are attracted to each other. They move towards each other and touch, establishing the current. When the magnetic field ceases, magnetization also ceases, and the elasticity of the contacts pulls them apart, cutting off the current.

It is frequently used as a limit switch for cylinders, or as a counting pulse generator: a permanent magnet attached to the moving part modifies the state of the switch as it passes by, thus transmitting information to the control device or counter.

Figure I.9: Reed switch

Switches are used to select between several active states of a device. They are therefore designed to cutoff, restore or reverse the direction of electric current as well as distribute it at will to different circuits. Universal switch, reversing switch, coupling switch, as well as multi-pole switches.

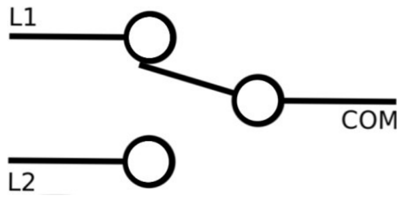


Figure I.10: Inverter symbol

2. Disconnector

disconnector is an electromechanical device symbolized by **Q** that mechanically separates an electrical circuit from its power supply, while physically ensuring an electrically satisfactory disconnection distance to isolate the part of the installation downstream of the disconnector.

The aim may be to ensure the safety of people working on the isolated part of the power network, or to eliminate a malfunctioning part of the network so that other parts can be used.

Unlike a circuit breaker or switch, a disconnecting switch has no breaking or closing action. It is imperative to stop downstream equipment to prevent it from opening under load. Failure to do so could result in serious burns due to arcing.

(a) (b) (c)

Figure I.11: Low-voltage disconnectors

(a) A visible electrical break (b) fuse holder (c) switch disconnector

There are several types of disconnectors on the market, of which there are two main categories:

Low-voltage disconnect switch:

This device is often fitted with fuses, in which case it is called a fuse-holder disconnector. Some disconnectors also feature pre-breaking contacts to cut off the control of power devices to preventon-load operation.

High-voltage disconnector:

The main function of a high-voltage disconnecting switch is to separate an element of an electrical network (high-voltage line, transformer, part of a substation, etc.) to enable an operator to carry out a maintenance operation on this element without risk of electric shock. High-voltage and low-voltage high-power disconnectors are often combined with an earthing system. This is a safety device, the purpose of which is to fix the potential of a previously de-energized installation to enable human intervention on an installation in complete safety.

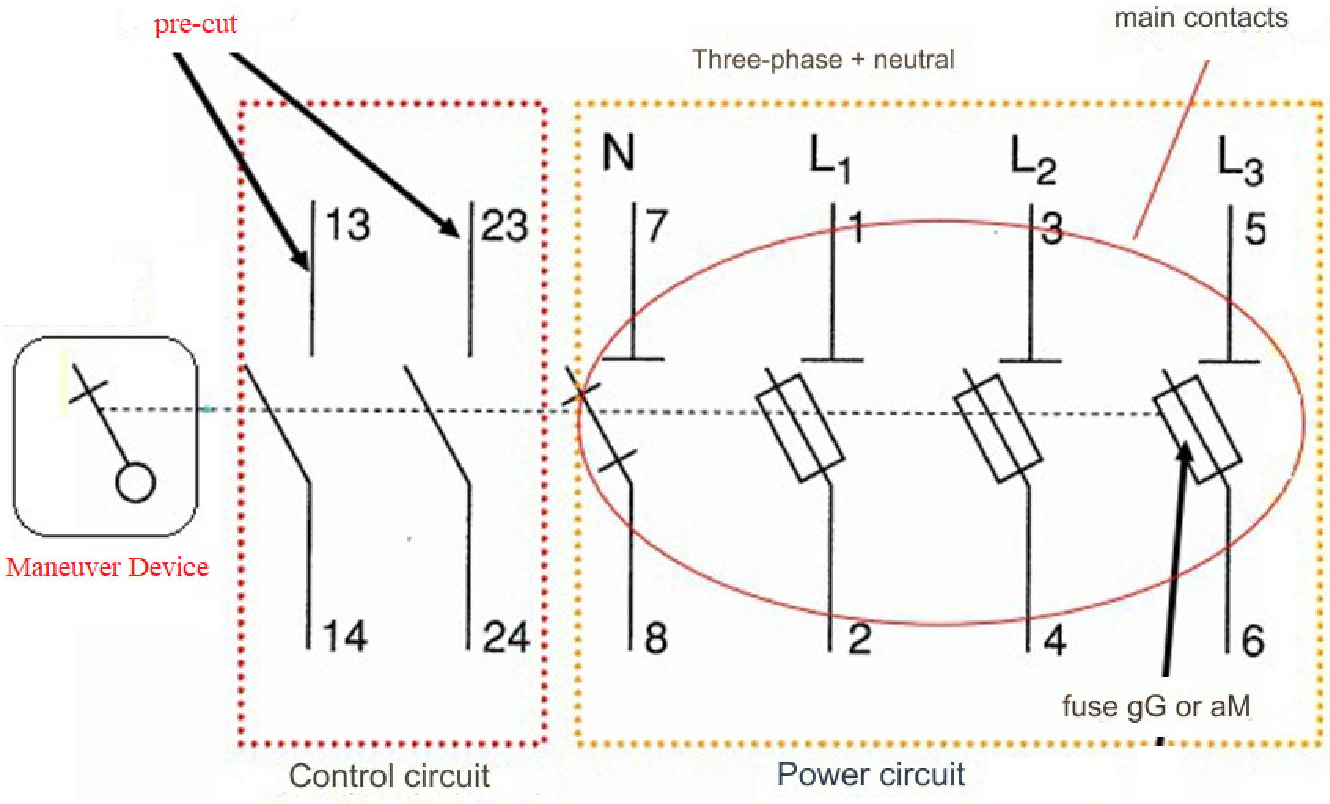


Figure I.12: Diagram and symbol of a three-phase disconnector

The operating principle and installation conditions are summarized in the following points:

• Mostly installed at the head of an electrical installation; • unambiguously indicate its position: this is sometimes referred to as a visible break

• Used to isolate an electrical circuit (power and control section) from the supply network, from which it must cut off all active conductors except the PEN.

• Unlike the switch-disconnector, the fuse-holder disconnector has no breaking capacity: it cannot disconnect an electrical circuit under load (rotating electric motor, powered heating elements, etc.);

• Is a safety device during maintenance: padlocked in the open position by an authorized maintenance technician, it prevents the system from being restarted, an operation also known as consignment?

• Can be operated from outside the electrical cabinet by means of a handle.

• Unlike the fuse-holder disconnector, the switch-disconnector has no associated fuse, so a short circuit protection system must be added to the circuit.

3. The contactor

The contactor is a control device capable of establishing or interrupting the passage of electrical energy to power high-power industrial motors (over 50 kW) and, in general, high-power consumers symbolized by **KM**. It performs the electrical switching function. It is capable of establishing, withstanding and interrupting currents under normal circuit conditions, including overload conditions, and therefore has **PdC** breaking capacity. The main advantage of this contactor is that it can be remotely controlled. It belongs to the family of pre-actuators, since it is located before the actuator in the energy chain. A contactor can be operated by any element of the control circuit (push- button, sensor, etc.).

It is also used in the home to power electrical appliances such as heaters and water heaters, as the control devices (thermostat, timer switch and other control contacts) could be quickly damaged by the excessive current.

Constitution

Contactors can be unipolar, bipolar, tripolar or tetra-polar, in other words they have one, two, three or four power contacts. On high-power contactors, the coils are often interchangeable, enabling the contactor to be operated with different voltages (24V, 48V, 110V, 230V, 400V).

The power circuit

This is a set of parts that conduct the contactor's main current. It consists of : Main contacts (1/L1- T1/2, 3/L2-T2/4, 5/L3-T3/6).

The power contactor comprises 4 functional assemblies:

• The main or power circuit
• The control circuit
• The electromagnet
• Auxiliary circuit (additional block).

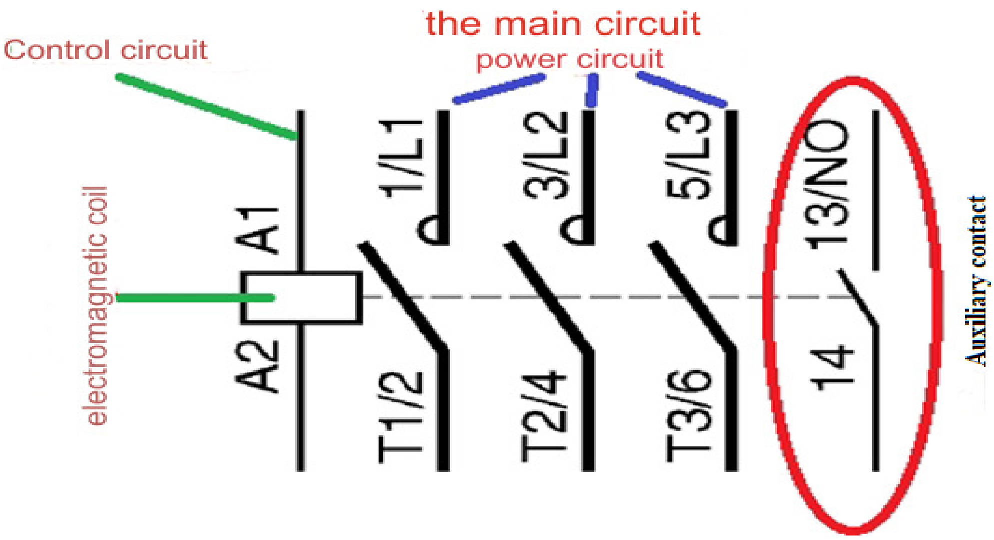


Figure I.13: Construction of a three-pole contactor

The control and signaling circuit It includes one, two or four control contacts for, for example, self-holding, signal lamps....

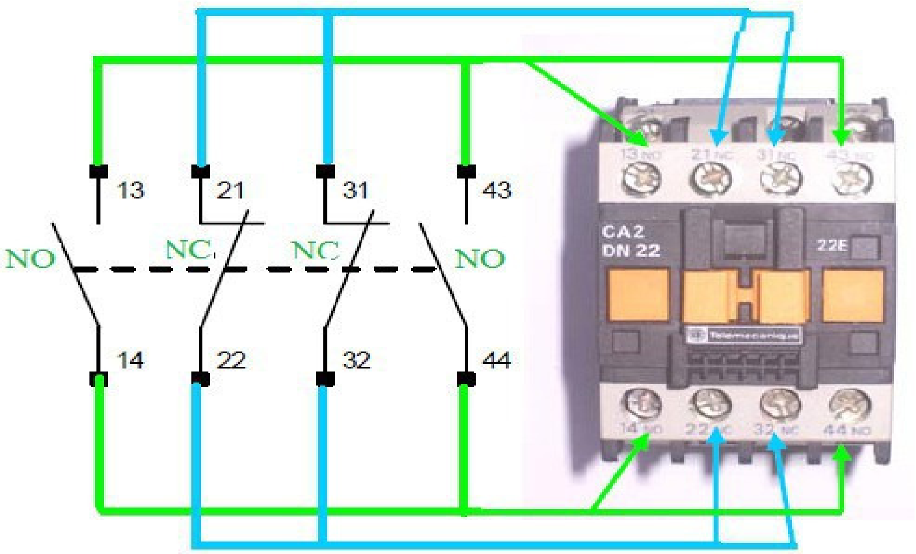


Figure I.14: Télémecanique contactor control contacts

Auxiliary contact block

The auxiliary contact block is a mechanical connecting device that fits onto contactors. It allows 2 to 4 additional contacts to be added to the contactor. The contacts are designed for use in the control section of circuits. They have the same designation and marking in the diagrams as the contactor on which they are installed (KA, KM...).

The auxiliary circuit is created by the addition of an auxiliary block, and is designed to perform other functions which essentially involve instantaneous and timed auxiliary contacts.

They are unique in that they are installed on the face.

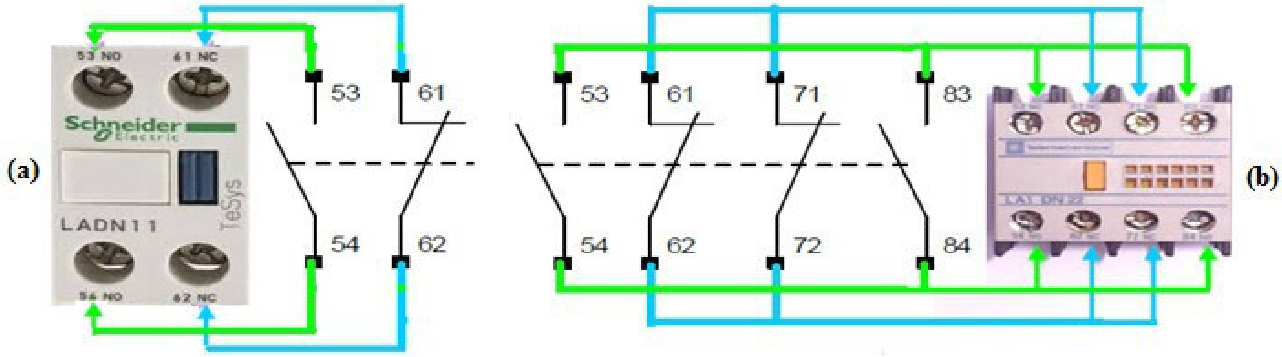


Figure I.15: Auxiliary contact block(a) bipolar and (b) tetra-polar

The driving force

The electromagnet is the element that attracts the power and control circuit contacts and the auxiliary circuit block simultaneously. It comprises :

• a coil supplied with AC or DC voltage at 24V; 48V; 110V; 230V; 400 V. It is identified by terminals A1, A2.

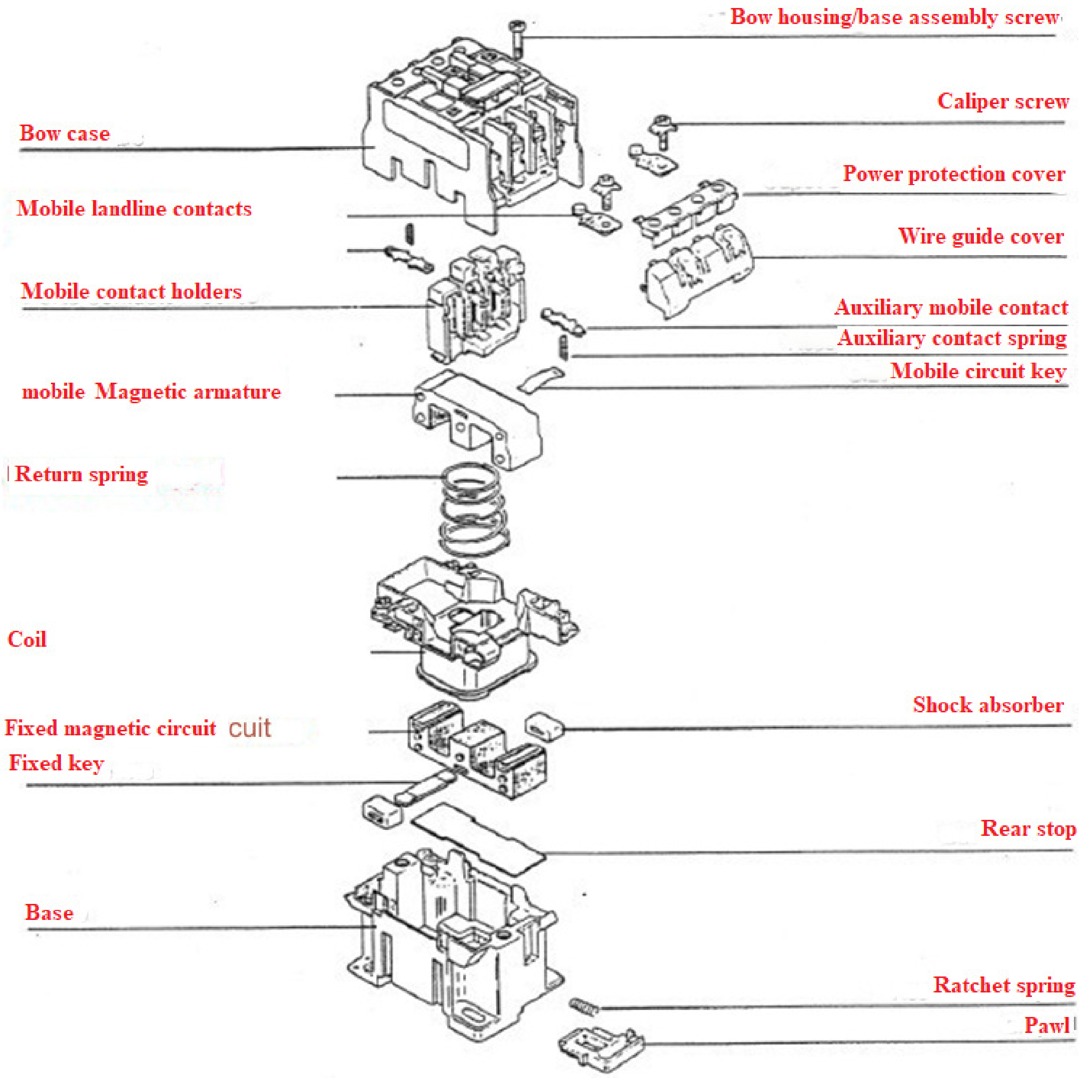


Figure I.16: Telemecanique contactor construction in detail

Criteria for choosing a contactor

The elements to be taken into account when choosing a contactor are :

-altitude above 3000m

-ambient temperature it exceeds 55°C around the device

-voltage (**Ue**) and rated operating current (**Ie**),

depending on the category of use

-the duty cycle

-electrical life

- **Use category**

The standardized use categories specify the current and voltage values for contactors based on :

-the nature of the receptors

-the conditions under which contactors close and open.

-Duty cycle (**m**).

This is the ratio between the duration of current flow and the duration of an operating cycle.

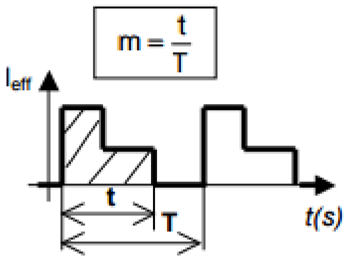


Figure I.17: Duty cycle m

-Electrical life:This is the number of load operations the main contacts can withstand without replacement.

-Altitude: affects the contactor's operating voltage and current. The contactors are designed to operate at altitudes of up to 3000m. Above this altitude down grade by 1% per 100m above 3000m.

-Temperature. T: ambient temperature outside the enclosure.

T: ambient temperature around the device.

K: coefficient of increase in intensity absorbed by the receiver.

Table I.1: coefficient of increase in current absorbed by the receiver as a function of temperature

T	40 °C	45 °C	50 °C	55 °C
t	55 °C	60 °C	65 °C	70 °C
k	1	1,18	1,25	1,35

The following table illustrates the categories of contactors to be used, taking into account the nature of the receiver and the conditions under which it closes and opens.

Table I.2: Contactor application categories for AC and DC empolyement:

4 AC employment categories:				
Category	Receiver	Functioning	I closing	I opening
AC1	Resistances (cos q≥ 0.95)	No overcurrent except fault	In	In
AC2	Wound rotor motor	Walk in fits and starts	7.In	7.In
AC3	Squirrel cage motor	Engine cut-off when running or stalled	7.In	In
AC4	Squirrel cage motor	Walk in fits and starts	7.In	7.In
5 DC employment categories:				
Category	Receiver	Functioning		
DC1	Low inductive load	L/R time constant ≤ 1 ms		
DC2	Bypass excitation motor	Engine cut-off when running or stalled		
DC3	Bypass excitation motor	Jog, Reversal of direction		
DC4	Series excitation motor	Engine cut-off when running or stalled		
DC5	Series excitation motor	Jog, Reversal of direction		

How to choose the right contactor for an electrical installation?

Illustrative example:

A unit heater is made up of a set of three-phase resistors with a power rating of 25kW and a squirrel-cage asynchronous motor capable of operating in ventilation or air extraction mode, with an effective power rating of 11kW, an efficiency of 80%, operating on a three-phase voltage of 400V, 50Hz and having a power factor of 0.8. Knowing also that this motor cuts in with the motor running, we ask:

How many contactors will be needed to control this electrical system?

Answer 1: Three contactors are used: KM1 heating, KM2 ventilation and KM3 extraction. In which application categories will they be used?

Answer2: KM1: Category AC1, KM2 and KM3:Category AC3

Answer3:

Calculation of line current for resistors **I_1= 25.10^3/(400x1.732)**, **I_1=36A**.

Calculation of the power absorbed by the motor :**Pa=Pu/efficiency=11x103/0.8=13750W** Calculation of the current consumed by the motor **I_2 = 13750/400.1.732.0.8= 24.8A**

To select the appropriate contactors for the system, we will refer to the manufacturer's catalog, for example **Schneider** :

KM1's choice :Category **AC1**

The choice of KM2 and KM3: Category **AC3**

Table I.3: Contactor catalog

The LC1 D25 choice

Maximum operating current (appliance in open air)

Contactor Size			LC1/ LP1 K09	LC1/ LP1 K12	LC1 D09	LC1 DT20	LC1 D12 DT25	LC1 D18 DT32	LC1 D25 DT40	LC1 D32	LC1 D38	LC1 D40A DT60A	LC1 D50A
Maximum cycle rate of maneuvers/hour			600	600	600	600	600	600	600	600	600	600	600
Connection according to IEC 60947-1	Section of cable	mm²	4	4	4	4	4	6	6	10	10	35	35
	Section of bars	mm	–	–	–	–	–	–	–	–	–	–	–
Operating current in AC-1 in A, following room temperature according to IEC 60947-1	≤ 40 °C	HAS	20	20	25	20	25	32	40	50	50	60	80
	≤60°C	HAS	20	20	25	20	25	32	40	50	50	60	80
	≤ 70 °C	HAS	(1)	(1)	17	(1)	17	22	28	35	35	42	56
Maximum operating power ≤ 60°C	220/230 V	kW	8	8	9	8	9	11	14	18	18	21	29
	240 V	kW	8	8	9	8	9	12	15	19	19	23	31
	380/400 V	kW	14	14	15	14	15	20	25	31	31	37	50
	415 V	kW	14	14	17	14	17	21	27	34	34	41	54
	440 V	kW	15	15	18	15	18	23	29	36	36	43	58
	500 V	kW	17	17	20	17	20	23	33	41	41	49	65
	660/690 V	kW	22	22	27	22	27	34	43	54	54	65	80
	1000 V	kW	–	–	–	–	–	–	–	–	–	–	–

Current

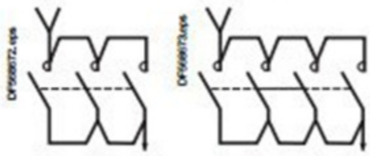
Category

(1) Consult our regional agency.
(2) With the LA9F2100 bracket set.
(3) With the LA9F2600 bracket set.
(4) LC1F115 to LC1F2600: for temperature 60 °C, the coil control voltage must not exceed the rated voltage Uc.

Increase in operating current by paralleling the poles

Apply to the currents or powers above the following coefficients which take into account an often unequal sharing of the current between the poles.

- 2 poles in parallel: K = 1.6.
- 3 poles in parallel: K = 2.25.
- 4 poles in parallel: K = 2.8.



The choice of KM2 and KM3: Category AC3

The choice

Operating current and power according to IEC (θ ≤60 °C) Contactor Size			LC1/ LP1 K06	LC1/ LP1 K09	LC1 K12	LC1 K16	LC1 D09	LC1 D12	LC1 D18	LC1 D25	LC1 D32	LC1 D38	LC1 D40A
Maximum operating current	≤ 440 V	A	6	9	12	16	9	12	18	25	32	38	40
Nominal operating power P(standarized motor powers)	220/240 V	kW	1.5	2.2	3	3	2.2	3	4.5	5.5	7.5	9	11
	380/400 V	kW	2.2	4	5.5	7.5	4	5.5	7.5	11	15	18.5	18.5
	415 V	kW	2.2	4	5.5	7.5	4	5.5	9	11	15	18.5	22
	440 V	kW	3	4	5.5	7.5	4	5.5	9	11	15	18.5	22
	500 V	kW	3	4	4	5.5	5.5	7.5	10	15	18.5	18.5	22
	660/690 V	kW	3	4	4	5.5	5.5	7.5	10	15	18.5	18.5	22
	1000 V	kW	–	–	–	–	–	–	–	–	–	–	–

Maximum frequencies of operating cycles/hour (5) Duty cycle	Power of employment					LC1 D09	LC1 D12	LC1 D18	LC1 D25	LC1 D32	LC1 D38	LC1 D40A
≤ 85 %	P	–	–	–	–	1200	1200	1200	1200	1000	1000	1000
	0,5 P	–	–	–	–	3000	3000	2500	2500	2500	2500	2500
≤ 25 %	P	–	–	–	–	1800	1800	1800	1800	1200	1200	1200

4. Fuses

Fuse-holder cartridges are safety devices that act as circuit-breakers. Conductors of electricity, they let electric current through up to a certain intensity: above their limit value, they melt (some are equipped with a melting indicator). By interrupting the electrical current, they protect circuits in the event of over current, thus avoiding the risk of fire and other problems.

Figure I.18: Different types of industrial fuses

Adapted to the line cross-sections used within the frame work of the NFC15-100standard, they are color-coded to express both :

- Rating in amperes (from 2 to 32A) indicates the maximum current that can be received.
- Fuse dimensions: from 8.5x31.5mm for the smallest to10.3x38mm for the largest. They're easy to spot, so you can choose the one that's right for you.

Fuses for electronic devices, in ceramic bodies, are designed for the specific protection of sensitive equipment and objects: dimmers, microcomputers

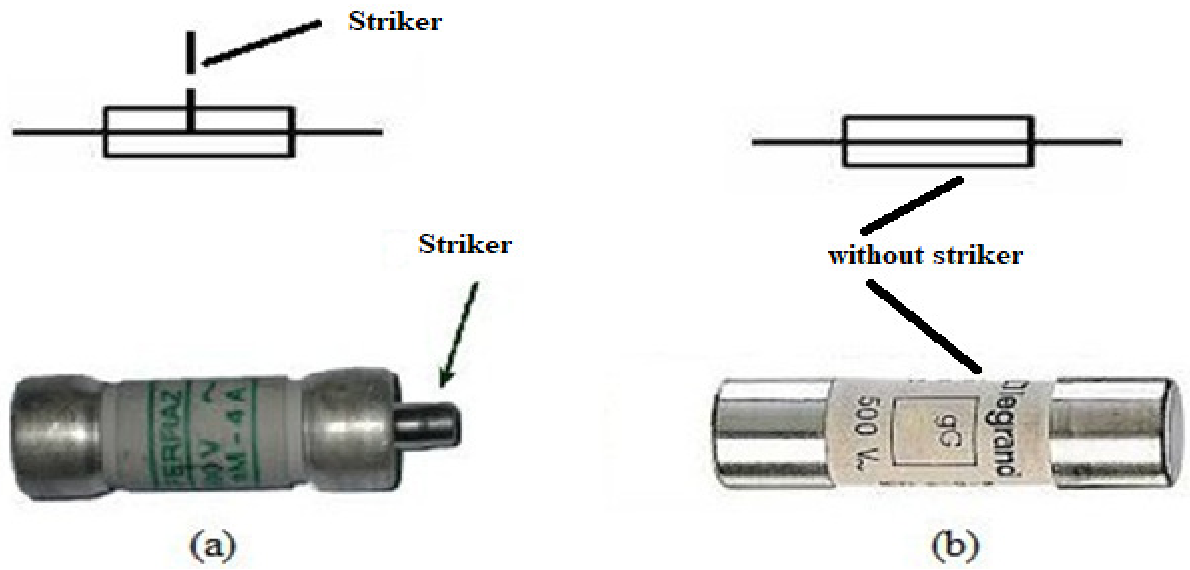


Figure I.18: Fuse symbols Internal structure of a fuse

The fuse element:

This is the heart of the fuse, and is sensitive to the RMS value of the current. Made of a material with very low resistivity, it takes the form of a wire or ribbon with a reduce dcross-section,creating a privileged melting zone.

a) The fuse body:

It is made of glass, ceramic or other equivalent materials.

b) Filler material:

Generally based on granular silica, it’s role is to absorb arc energy and ensure insulation after the cut.

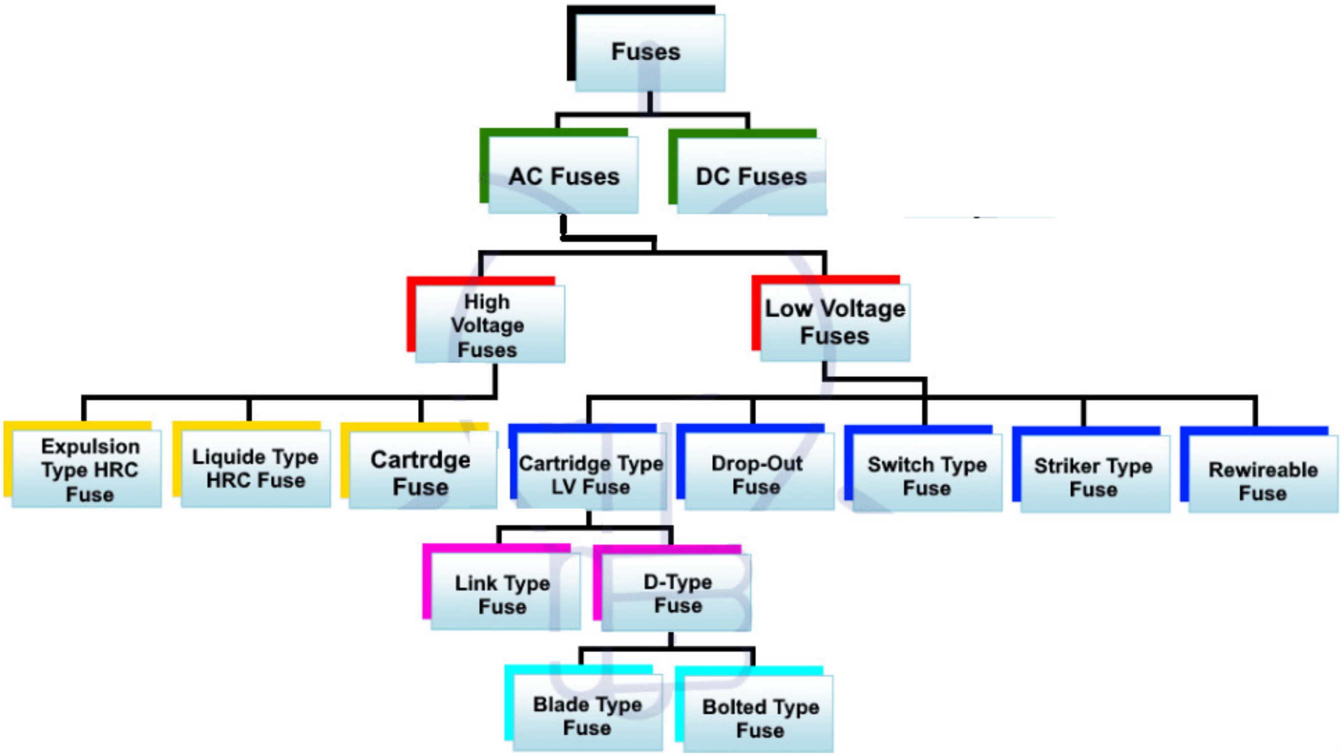


Figure I.19: Classification and Types of Fuses

How it works

a) At rated current In, the energy dissipated by the Joule effect is dissipated without causing the fusion. Thermal equilibrium does not cause the fuse to age or deteriorate.

In the event of over current, thermal equilibrium is broken. The fusible element receives more energy than can be evacuated. This is fusion.

Fuse cartridge classes:

Thereareseveralclassesoffusetomeetthetechnicalrequirementsoftheelectricalinstallationsto be used.

- **Class AM** (Accompanying motor) a remarked in green, Slightly delayed fuses for motor circuits or circuits with starting current (Id= 5 to 10 times In)

- **Class gI** (Industrial group)new standard **gG** a remarked in black color

Fast fuses for circuits without inrush current, such as lighting circuits, heating circuits, etc.

- **Class gF**(domestic cartridge) a remarked in black

Quick-acting fuses for domestic installations, with the same characteristics as gG fuses, but without sand inside the cartridge, which reduces both price and breaking capacity.

- **Class AD** (distribution subscription)a remarked in red

-**Class UR:** Ultra-fast(***UR)***fuses protect power semiconductors and DC circuits.

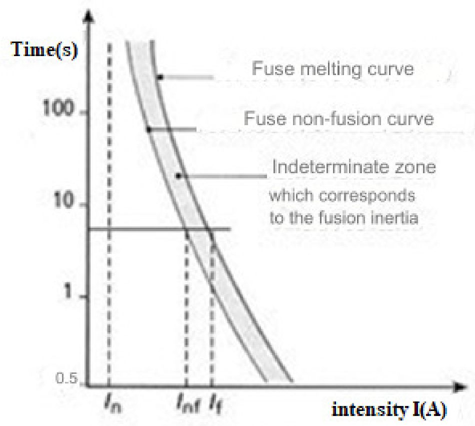
Size	Caliber range	Type
8,5 x 31,5	1 - 16 A	gG
10 x 38	0,5 - 25 A	
14 x 51	2 - 50 A	
22 x 58	4 - 125 A	
8,5 x 31,5	1 - 10 A	aM
10 x 38	0,25 - 25 A	
14 x 51	2 - 50 A	
22 x 58	16 - 125 A	
00	25 - 160 A	Knife gG
0	63 - 200 A	
1	125 - 250 A	
2	200 - 400 A	
3	500 - 630 A	
4	630 - 1250 A	
00	25 - 125 A	Knife aM
0	63 - 160 A	
1	125 - 250 A	
2	200 - 400 A	
3	500 - 630 A	
4	630 - 1000 A	

Figure I.20: Legrand's range of industrial fuse cartridges

- **Rated currents and voltages** The rated current can pass through a fuse indefinitely without melting or overheating; the rated voltage is the voltage at which the fuse can be used.
- **Conventional non-melting and melting currents Conventional non-melting current**(Inf): value of the current which can be supported by the fuse cartridge for a conventional time without melting".
- **Conventional melting current** (If): "current which causes the fuse cartridge to melt before the conventional time has expired.

gauge in Amps(A)	Inf Intensity of non fusion	If Intensity of fusion	t conventional time
$I_n < 4$	$1{,}5\ I_n$	$2{,}1\ I_n$	1 h
$4 < I_n < 10$	$1{,}5\ I_n$	$1{,}9\ I_n$	1 h
$10 < I_n < 25$	$1{,}4\ I_n$	$1{,}75\ I_n$	1 h
$25 < I_n < 63$	$1{,}3\ I_n$	$1{,}6\ I_n$	1 h
$63 < I_n < 100$	$1{,}3\ I_n$	$1{,}6\ I_n$	2 h
$100 < I_n < 160$	$1{,}2\ I_n$	$1{,}6\ I_n$	2 h
$160 < I_n < 400$	$1{,}2\ I_n$	$1{,}6\ I_n$	3 h
$400 < I_n$	$1{,}2\ I_n$	$1{,}6\ I_n$	4 h

(a)



(b)

Figure I.21: Time-intensity characteristics of melting and non-melting

Pre-arc and arc thermal stresses

A fuse breaks a short-circuit in two stages: pre-arcing and arcing. The pre-arc thermal stress corresponds to the minimum energy required for the fuse element in the cartridge to start melting. It is important to know this thermal stress to determine the selectivity on a short-circuit between several protection systems in series.

The thermal arc stress corresponds to the energy limited between the end of the pre-arc and total cut-off.

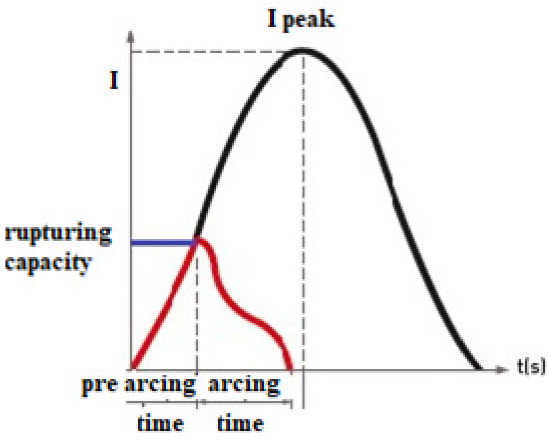


Figure I.22: Pre-arcing and arcing thermal stresses

Rupturing capacity of a fuse means the maximum power a circuit breaker can interrupt under a fault. It is usually expressed in Mega Volt Ampere (MVA) and it is then the product of the rated breaking current in kilo amperes and rated voltage expressed in kilovolts.

Thermal stresses of a fuse cartridge(I^2t)

This is the energy per unit resistance required to melt the fuse. This thermal stress must be lower than that of the installation to be protected.

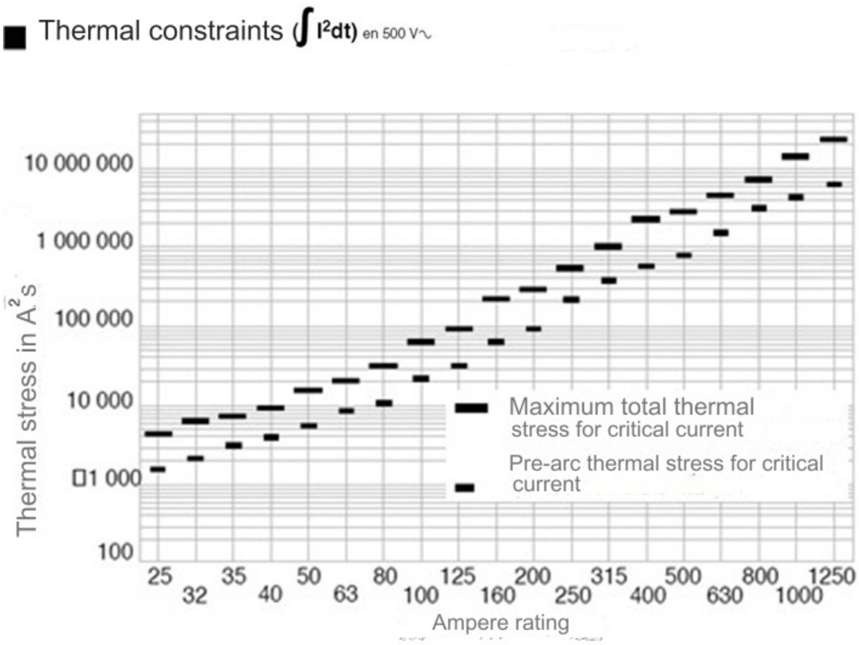


Figure I.23: Thermal stresses on a fuse cartridge(I^2t)

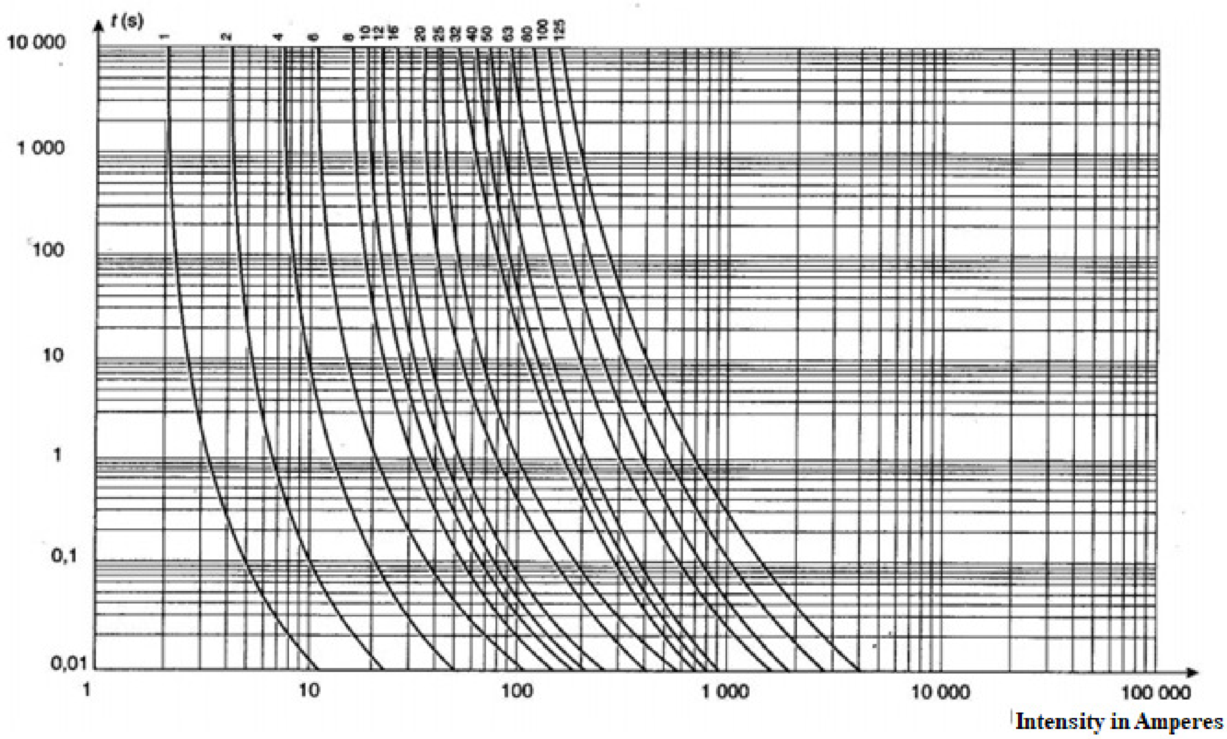


Figure I.24: Melting curves for gG fuse cartridges

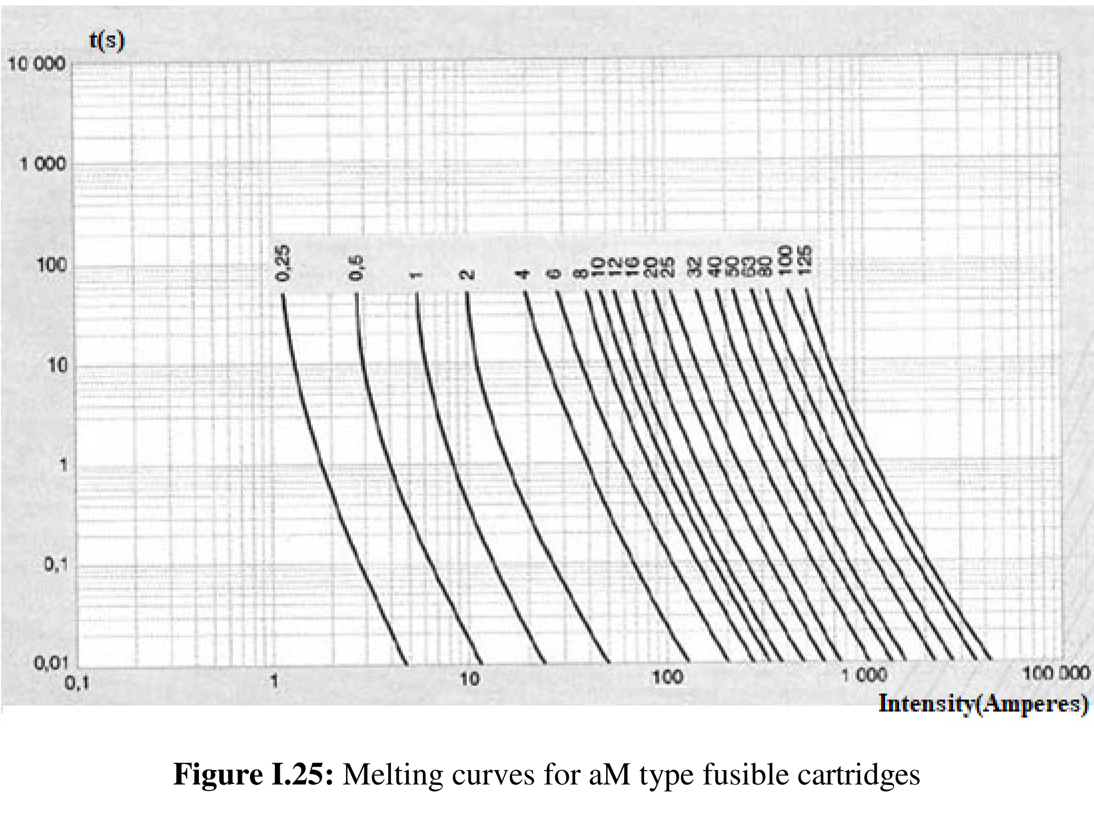


Figure I.25: Melting curves for aM type fusible cartridges

5. Thermal relay

Thermal relays protect electric motors against overloads. To do this, it constantly monitors the current in the receiver.

In the event of an overload, the thermal relay does not act directly on the power circuit, but acts on control contact 95-96, from where it opens the control circuit which de-energizes coil A1- A2 of contactor KM, and the current flowing through the receiver is cut off.

The thermal relay is represented by the letter **F**on the diagrams.

How it works :

The thermal relay consists of a metal bimetallic strip (two blades with different temperature coefficients). The passage of current, if it exceeds the relay's set value, causes the bimetallic strip to heat up and deform. An electrical contact associated with this bimetallic strip triggers the control circuit.

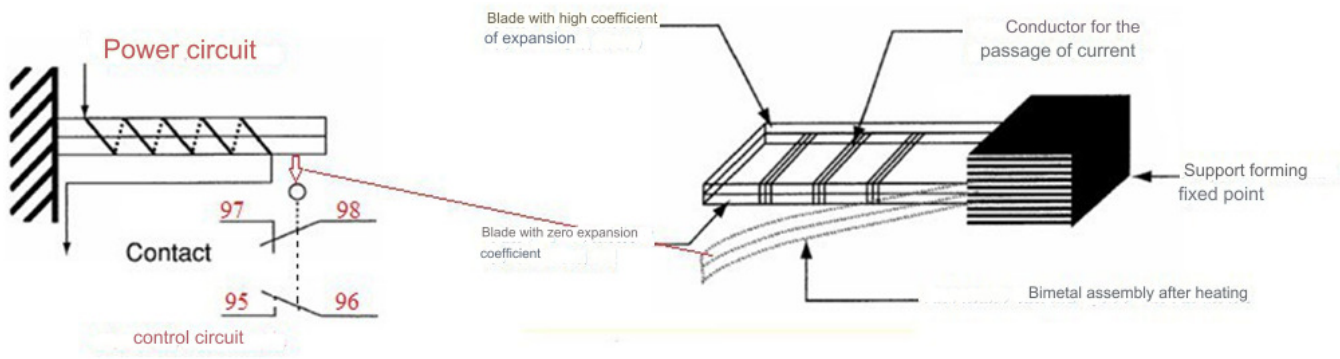


Figure I.26: Thermal relay operating principle

In the event of a phase break or imbalance in the three phases of a motor's power supply, the so-called differential device acts on the thermal relay trip system.

✓ Temperature compensation principle:

To prevent unwanted tripping due to variations in ambient temperature, a compensation bimetallic strip is fitted to the main tripping system. This compensation bimetallic strip deforms in the opposite direction to the main bimetallic strips.

The main or power circuit is integrated between the contactor and the motor. It consists of

:

3 main contacts (1/L1-2/T1, 3/L2-4/T2,5/L3- 6/T3)

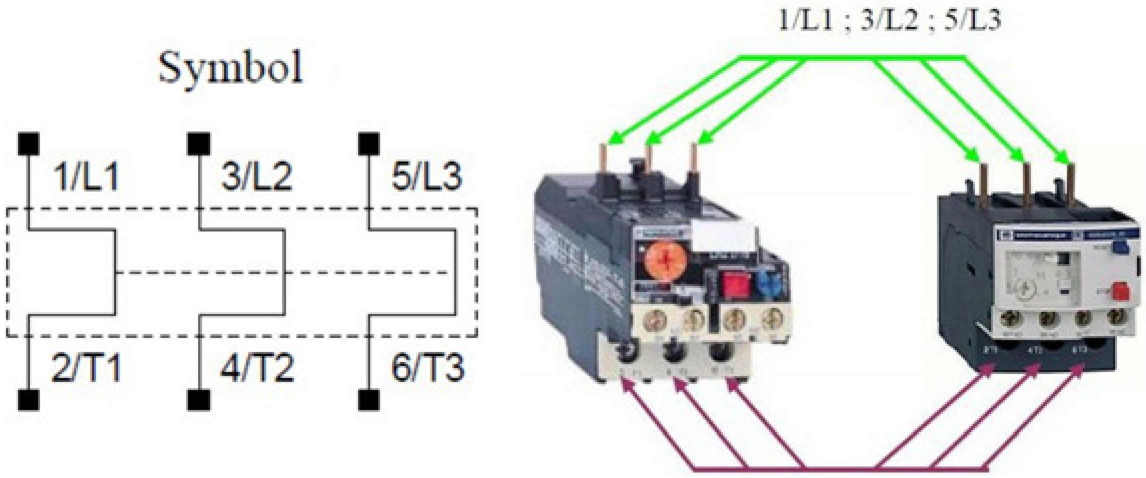


Figure I.27: The thermal relay power circuit

The control circuit includes two control contacts Control contact (NO/97-98;NC/95-96)

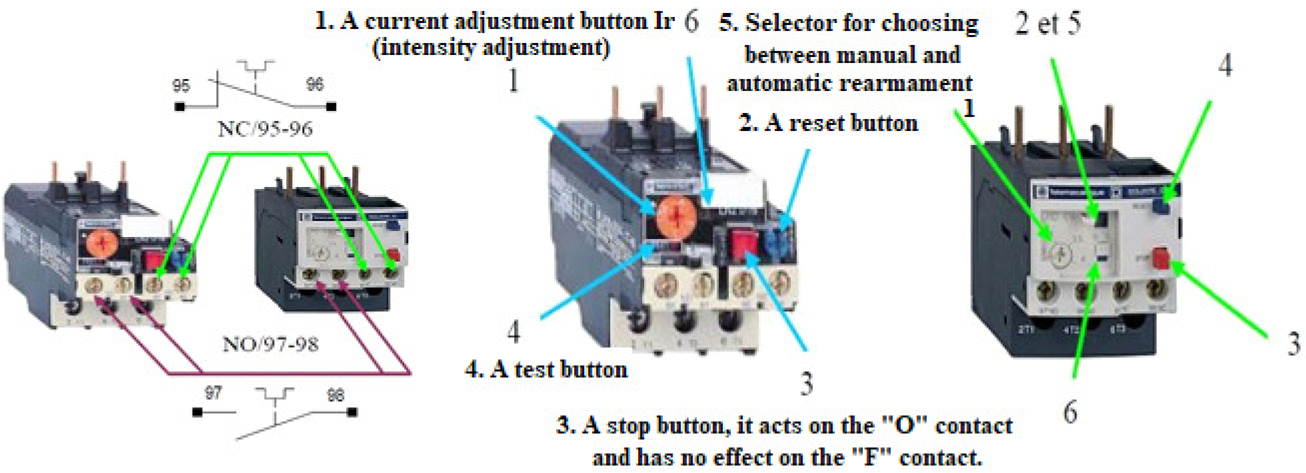


Figure I.28: Thermal relay control circuit

- ✓ **Auxiliary contacts:** Thermal triggers activate two contacts, one of which is connected to the other. is NC and the other is NO. The NC contact interrupts the excitation current to the contactor coil, thus enabling the motor to be switched off when required. The make contact can be used for a variety of purposes.
- ✓ **Reset button:** The reset button is used in both automatic and manual positions.
  In automatic position (A), when the bimetallic strips have cooled down, the relay switches on the contact 98-97 automatically. In manual position(M), for the contact or to return to service, the reset button must be pushed after the bimetallic strips have cooled down.
- ✓ **Test button**: Pressing the test button tests whether the contact is in the service or out of the service.
- ✓ **Stop button:** Stop button is used to stop the engine in an emergency.

The thermal relay can be combined with three-phase, single-phase and direct-current motors as shown in the figure below.

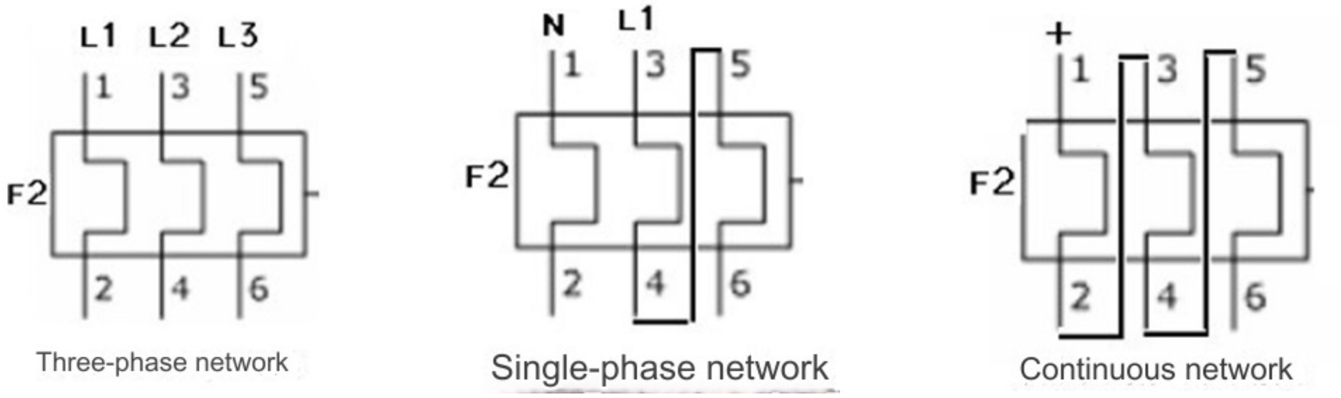


Figure I.29: Thermal relay association diagram with three-phase, single-phase or DC motors

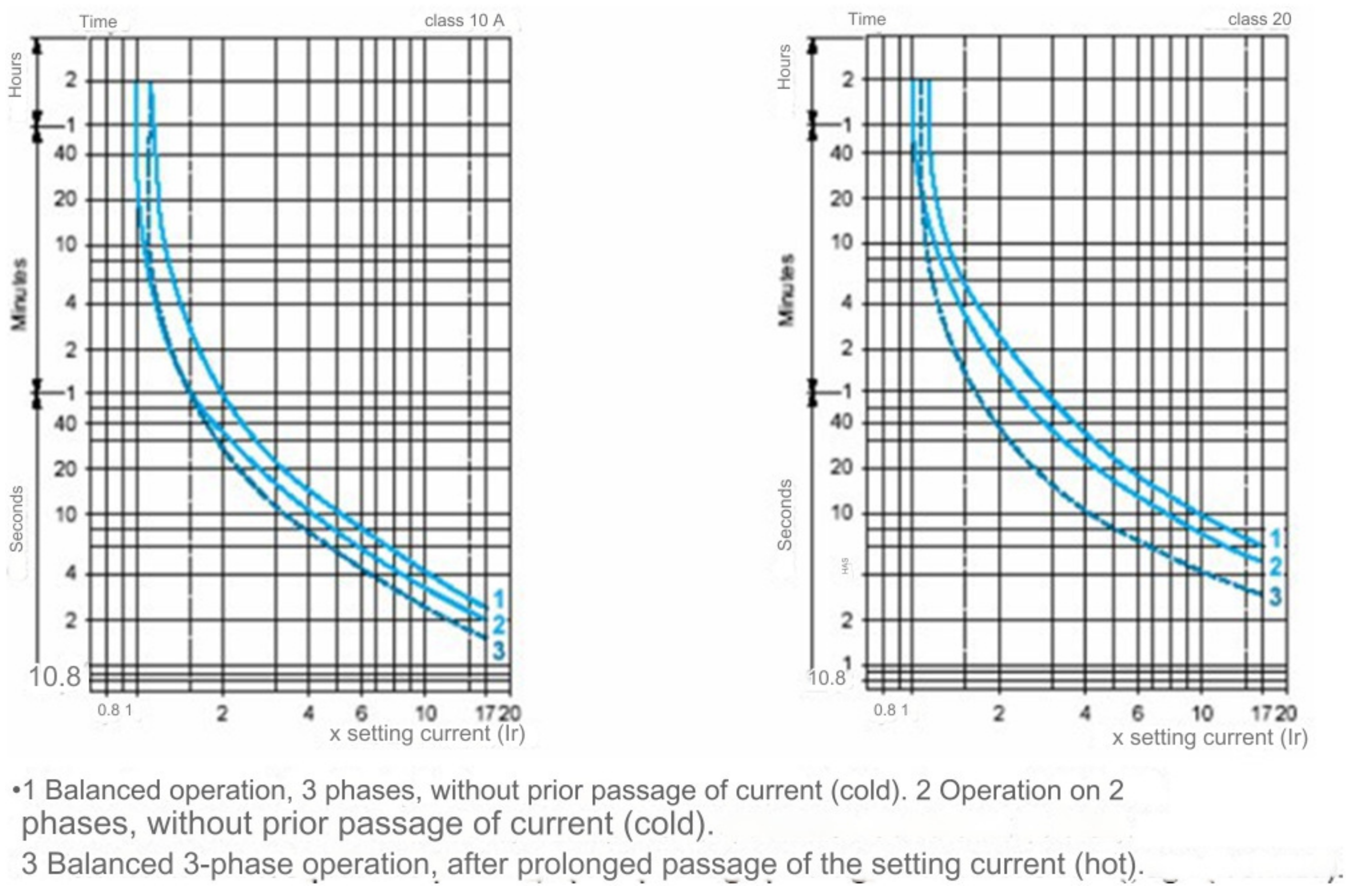


Figure I.30: Average operating time as a function of control current

✓ **Criteria for choosing a thermal relay**

- Operating voltage
- Adjustment range
- Employment current

- start-up time(class10,20or30)
- The set current (Ir) must be equal to the rated current (In) shown on the motor nameplate.

Illustrative example: Given a motor drawing 5A of current, choose the appropriate thermal relay and fuse?

Referring to the manufacturer's catalog in the figure below

For a motor consuming 5A,you can choose either a LRD10 inclass10Aor a LRD1510 in class 20, depending on the motor starting time.

The setting range for each thermal relayis 4 to 6A.

Thermal relays are to be combined with aM (Motor Accompaniment) 8A fuses or a gG16A fuse.

The thermal relay will be set to In of the motor, i.e.5A.

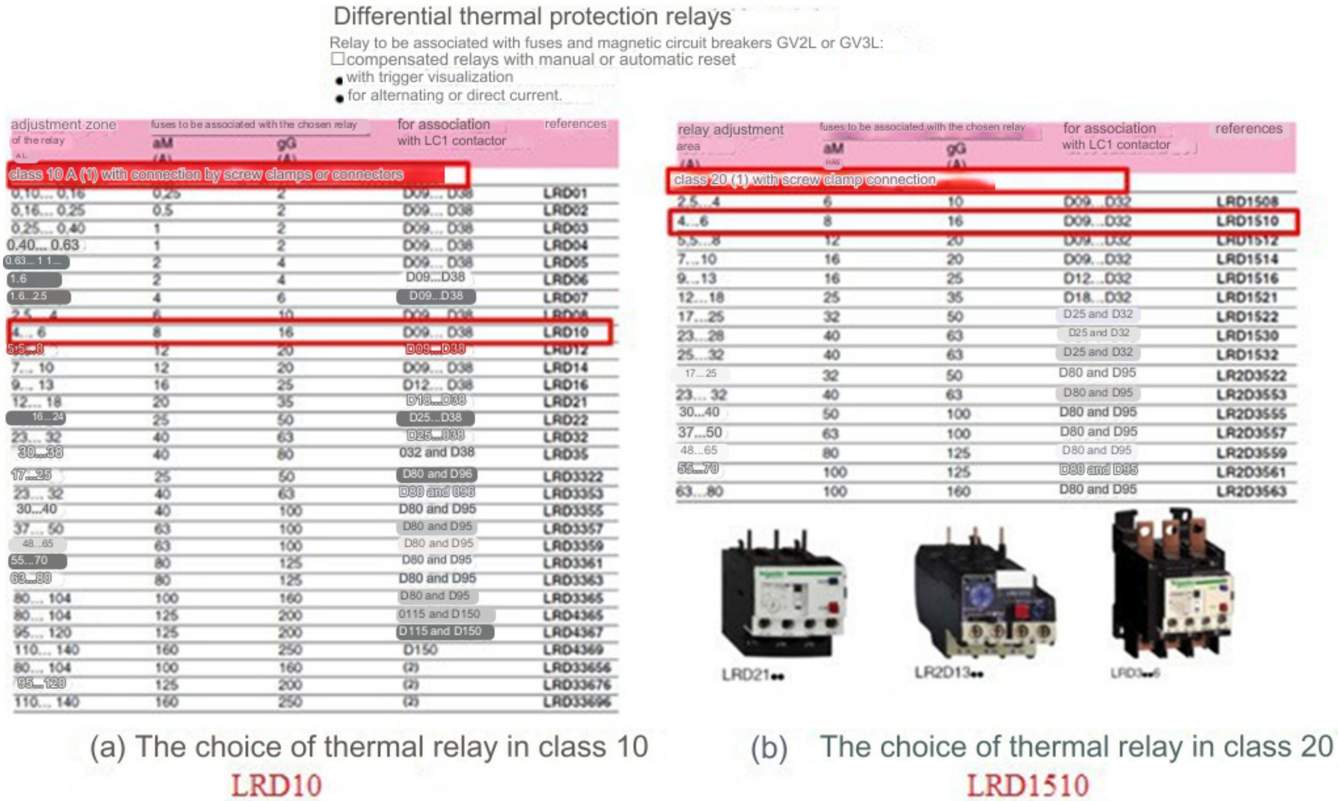


Figure I.31: Standard range of thermal relays

6. Electromagnetic relays

The electromagnetic relay is an electromagnetic switch that can be operated with low-value direct or alternating current (tens of milliamperes). The switching part is used to control high-power mains loads (several tens of amperes).

Constitution:

The relay consists mainly of a coil which, when energized, creates an electromagnetic field that transmits a mechanical force to an electrical contact switching system.

Depending on specifications and requirements, the electromagnet (coil) can be supplied with

VLV(Very Low Voltage)(5V,12V,24V,48V)direct or alternating current, or LV(Low Voltage) (230 V, 400 V).

The switching system can be composed of one or more single-effect switches called normally open (NO) or normally closed (NC) contacts. These switches are adapted to the current and voltage range to be transmitted to the power section.

Various mechanical or pneumatic systems can create a delay on engagement or release (the relay is then said to be "timed").

In high-power systems, relays are called "contactors".

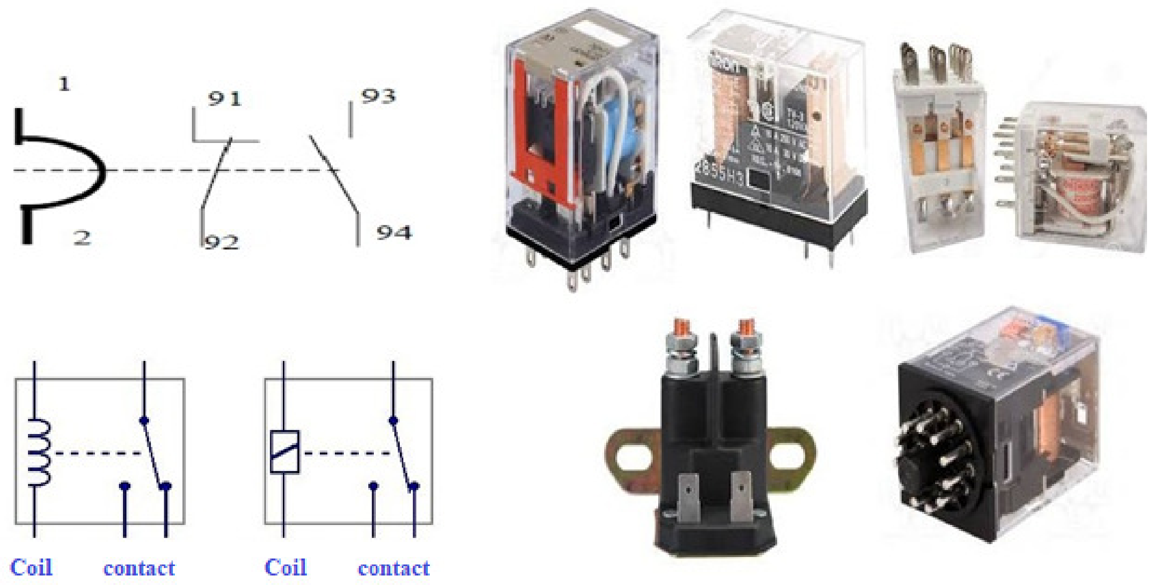


Figure I.32: Constitution and symbol of the electromagnetic relay.

Operating principle.

Supplying current to the coil magnetizes the circuit, which closes and activates the contact.

- ✓ A relay can be monostable or bistable:
- ✓ **Monostable operation**: the contacts switch when the coil is energized and the Return to the initial state occurs when the coil is no longer energized By means of a (to general). This is the most widely used relay.
- ✓ **Single-coil bistable operation**: power is supplied to the coil so that the contacts switch: the state does not change when the coil is de-energized; a mechanical system blocks the return. To return to the initial state, the coil is powered again to unlock the mechanism, in some cases by

reversing the polarity of the power supply.

- ✓ **Two-coil bistable operation:** power is supplied to the first coil so that the contacts switch: the state does not change when the coil is no longer energized. To return to the initial state, the second coil is energized.
- ✓ When current flows through the coil (control circuit), it creates a magnetic field which causes the contacts (power circuit) to close. When the current is cut, a return spring reopens the contacts.

Nominal supply voltage (Un): value of the coil supply voltage for optimal operation.

Excitation coil resistance (Rcoil): This parameter characterizes the electrical resistance of the relay excitation circuit.

Nominal current (In): value of the current flowing in the coil for optimal operation (In = Un / Rcoil)

Relay cut-in voltage: minimum value of the coil supply voltage allowing the switches to move to the working position.

Relay tripping voltage: maximum value of the coil supply voltage allowing the switches to return to the resting position.

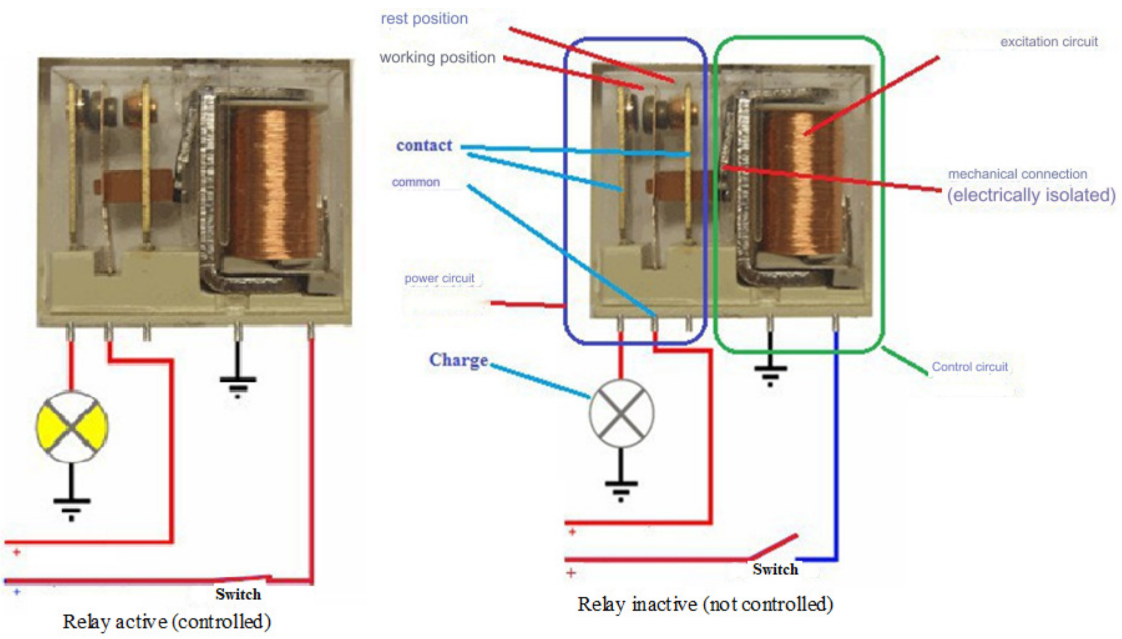


Figure I.33: Operating principle of an electromagnetic relay

b- Power part :

Type of contacts: A relay may contain several contacts. These contacts can be NC (normally closed), NO (normally open), change over or timed.

Maximum current that can flow through the contacts

Breaking capacity: maximum power the switch can withstand Operating voltage: voltage across the switch when it is open Maximum number of possible operations

Switch contact resistances Tripping or cut-in times

- **Disadvantages of electromechanical relays:**

- it can be relatively noisy
- it has a limited lifespan, as moving parts wear out. When an element needs to be controlled very often, electronic components (solid-state relays, transistors, etc.) are used instead.

7. The circuit-breaker

The circuit breaker is an electrical connecting device capable of establishing, withstanding and interrupting currents under normal circuit conditions, as well as establishing, withstanding for a specified time and interrupting currents under specified abnormal conditions such as short-circuit or overload.

An earth leakage circuit breaker (ELCB) is a differential switch that also provides protection against short-circuit current (overload).

The principle of a residual current device (*RCD*) is to ***compare*** the currents on the different conductors passing through it. For example, in single-phase, it ***compares*** the current flowing in the phase conductor with that in the neutral conductor. It is a device for protecting people and detecting earth leakage currents in electrical installations.

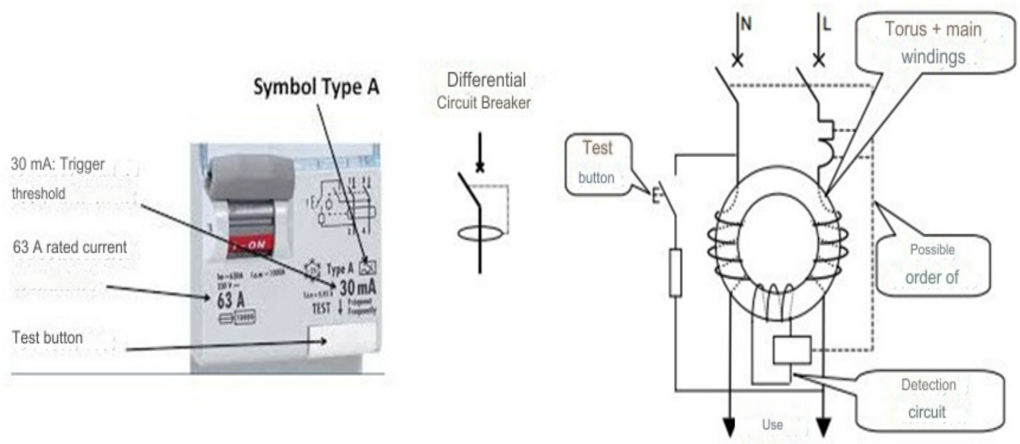


Figure I.34: Principle of the differential circuit breaker

The residual-current device is based on the following principle: in a normal installation, the electric current flowing in one conductor must flow out another. In a single-phase installation, if the current in the phase conductor at the start of an electrical circuit is different from that in the neutral conductor, there is a leak. The difference in current intensity to which a circuit breaker reacts is called the "differential sensitivity of the circuit breaker" (mandatory *30 mA* on domestic terminal circuits), noted ***IΔn*** ("i delta n").

How it works is very simple: each conductor passes through a magnetic toroid, forming electromagnetic fields of identical strength that cancel each other out. In the event of a difference, hence the name *differential*, the resulting electromagnetic field activates a device that immediately cuts off the current.

The rated residual differential current, note dIΔn, is the maximum value of the differential current that should cause the device to operate. Its value commonly expresses the sensitivity or setting of the RCD (e.g. 30 mA RCD). From the point of view of differential product standards, a residual current device can trip at half its rated residual current.

The setting threshold is called sensitivity.

The standard tolerates an operating range:

- $Id < I\Delta n/2$: Not triggered ;
- $I\Delta n/2 \leq Id < I\Delta n$: Possible triggering ;
- $Id \geq I\Delta n$: Triggering assured.

Settings:

- Whatever the earthing scheme: High sensitivity ($I\Delta n \leq 30mA$)for tapped circuits comfort

A distinction is made between:

- Medium sensitivity:650, 500,300,100 mA
- High sensitivity: 30, 12, 6 mA

Thermal-magnetic circuit breaker

A thermal-magnetic circuit breaker is a protective device whose function is to interrupt the electric current in the event of an overload or short-circuit.

A-Thermal protection:

Each motor phase is protected by a bimetallic strip (thermal trip device) which, in the event of prolonged over current, heats up by Joule effect and triggers a mechanism which opens the contacts. The tripping threshold can be set directly on the motor circuit-breaker.

B-Magnetic protection:

A trip unit fitted with an electromagnet protects each phase and, in the event of a short- circuit, cuts off the electric current. This trip unit is based on the creation of an instantaneous magnetic field (0.1sec) which activates a moving part and commands the contacts to open. The magnetic part of the motor circuit-breaker is not adjustable; it is the tripping curves that define the tripping threshold, expressed as a number of times the rated current (3 to 15 In).

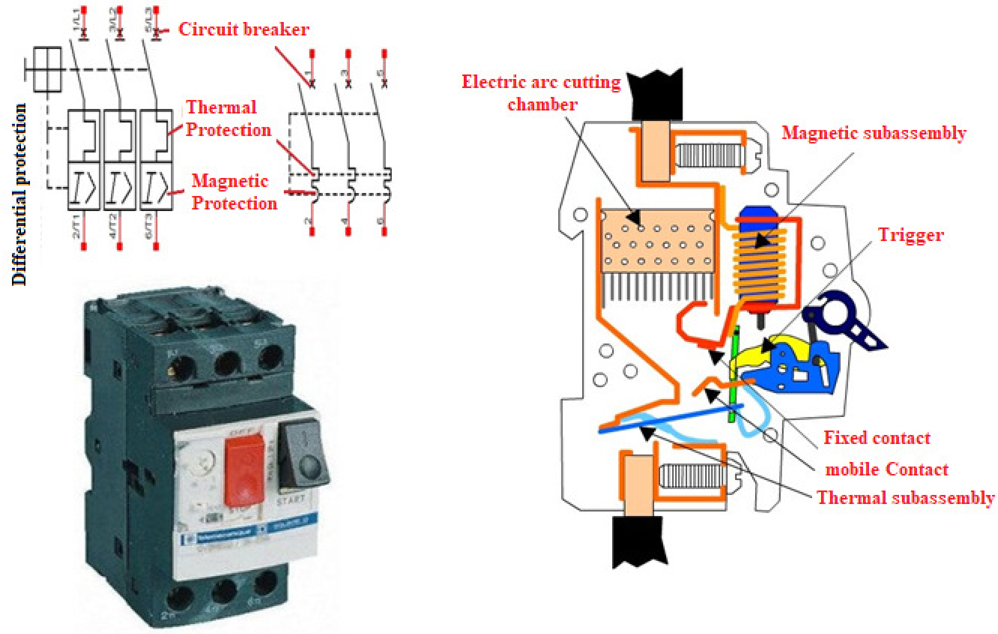
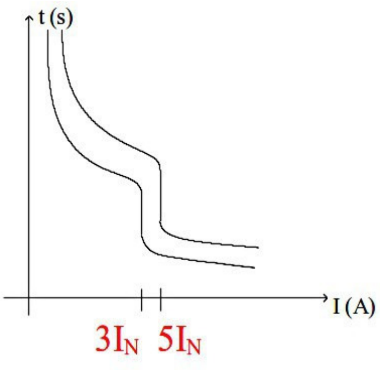


Figure I.35: Construction of a thermal-magnetic circuit breaker

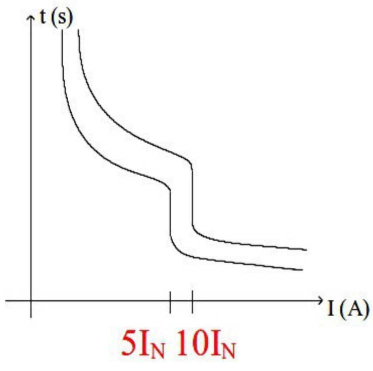
Choosing a circuit breaker:

- I_N: rated operating current (found from I_B with $I_N \geq I$)$_B$
- U_N: nominal operating voltage
- Breaking capacity (must be greater than short-circuit current)
- Number of switching poles:single-phase,single,single+neutral,two-pole (2 phases), three-phase (three-pole) or three-phase + neutral (four-pole)
- Type of circuit-breaker curve: the type of curve depends on the receiver being protected (inrush current on power-up) and defines the breaking terminals of the magnetic part of the circuit-breaker. Example of the most common curves:

Curve B :



Curve C :



Curve D:

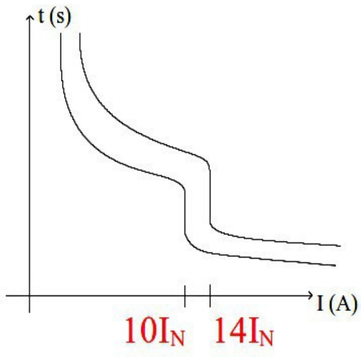
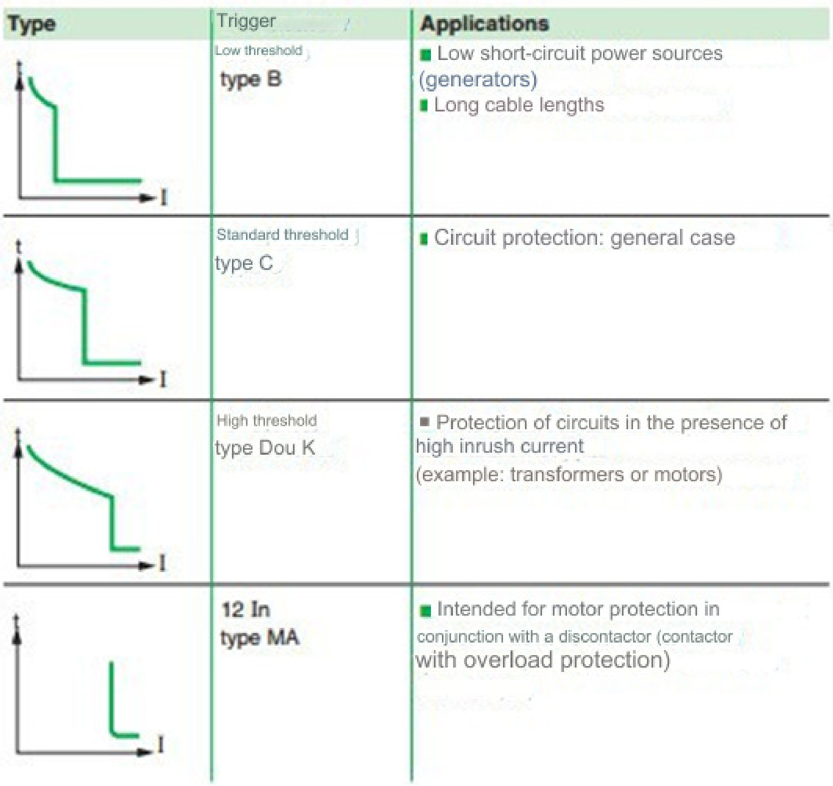


Figure I.36: Types of circuit breaker curves

For example, for a 2A curve B circuit breaker, the magnetic cut-off zone is between 6A (3×IN) and 10A (but we don't know where exactly). What we do know is that it cuts out when the current exceeds 10A, and does not cut out when the current is less than 6A.



Type	Trigger	Applications
	Low threshold type B	■ Low short-circuit power sources (generators) ■ Long cable lengths
	Standard threshold type C	■ Circuit protection: general case
	High threshold type Dou K	■ Protection of circuits in the presence of high inrush current (example: transformers or motors)
	12 In type MA	■ Intended for motor protection in conjunction with a discontactor (contactor with overload protection)

Figure I.37: Types of triggers and their applications

Trigger selection

The trip unit is a removable, adjustable device that can be associated with the circuit-breaker to open the circuit-breaker poles in the event of a fault (short-circuit, overload). It can be either magneto-thermal or electronic. The latter allows greater precision and more flexible adjustment.

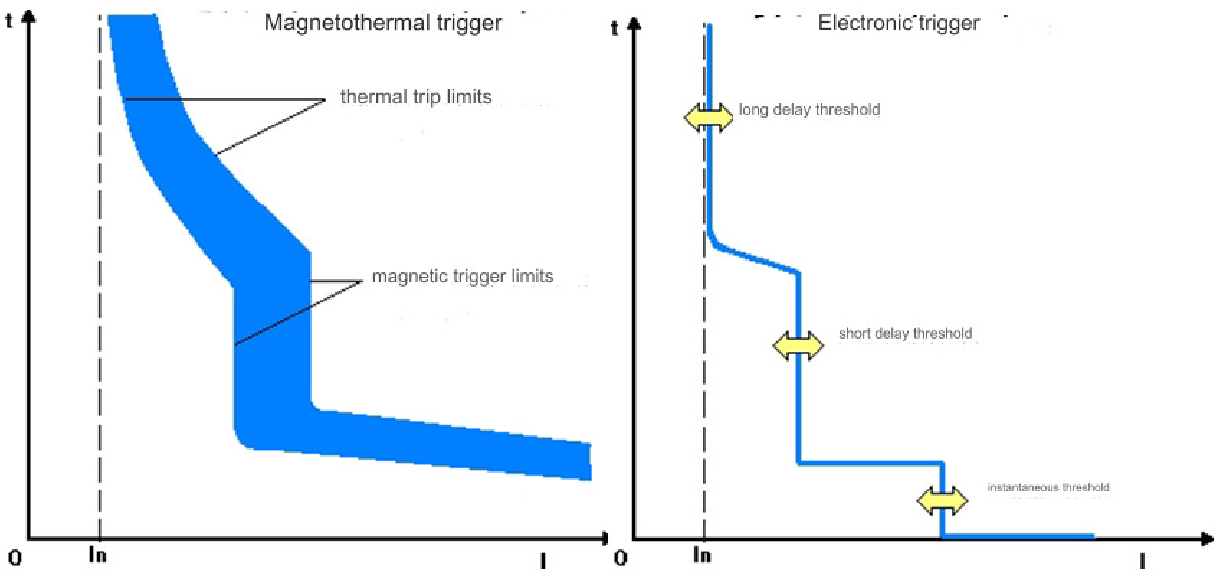


Figure I.38: Magneto thermal trip curves versus electronic trip curves

Figure I.39: COMPACT C125H circuit-breaker with trip unit

To set the trigger,   select manually the type of curve to be used, depending on the application.

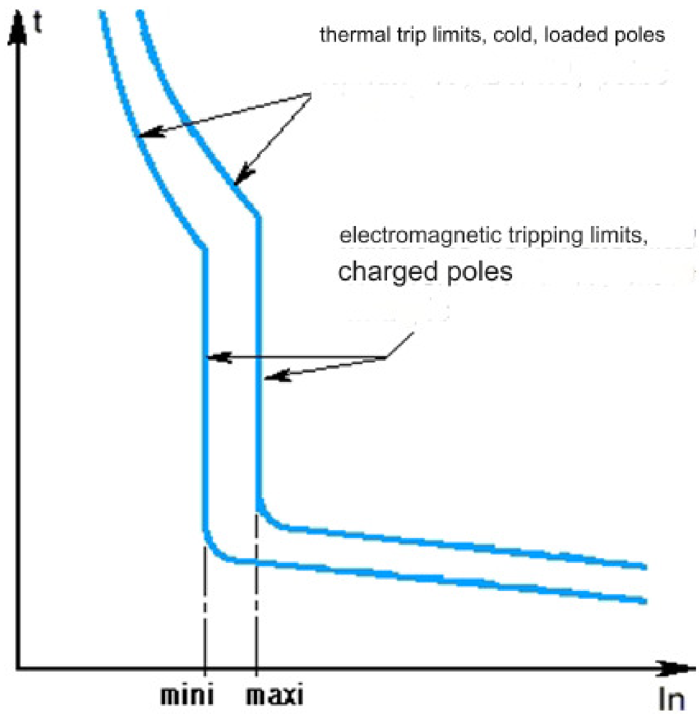
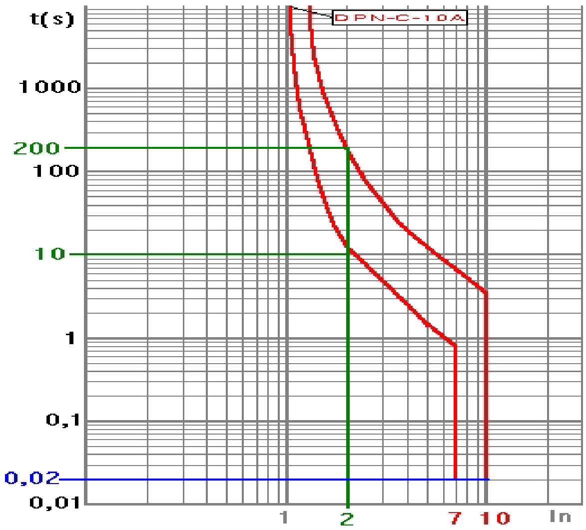


Figure I.40: Magneto thermal tripping curves

The following table illustrates the setting of the magnetic release according to the IEC standard 947.2.

Curve type	Setting the magnetic release in accordance with IEC 947.2		Application
	mini	max	
B	3.2 In	4.8 In	Long cable runs
C	7 In	10 In	Conventional receivers
D or K	10 In	14 In	High current draw
MA	12 In		Engine starter
Z	2.4 In	3.6 In	electronics

Example: If we want to set the Multi 9DPNC10 circuit-breaker for conventional receivers, the trip curve will look like the figure below.



Circuit breaker Multi 9DPNC 10

Type C curve

In=10A

Magnetic tripping: 7 to 10 In

(70 to 100A)

In 20ms maximum

Thermal trip: between 10s and 200s for 2 In (20A)

Figure I.41: Multi 9DPNC10 circuit-breaker trip curve

Selectivity

Selectivity is based on the coordination between the operating characteristics of the protective devices in such a way that when over currents within given limits occur, the intended device intervenes while the others, placed upstream, do not intervene.

Due to the selectivity between protection devices A and B, a fault occurring down stream of B does not affect other parts of the installation.

Selectivity improves service continuity and installation safety. Standard NF C 15-100 distinguishes 2 types of selectivity: **partial** selectivity and **total** selectivity.

It is the coordination of circuit breakers in such away that a fault occurring at any point in the installation is eliminated by the circuit breaker immediately upstream of the fault, and by it alone. It is the coordination of circuit breakers in such a way that a fault occurring at any point in the installation is eliminated by the circuit breaker immediately upstream of the fault, and by it alone .

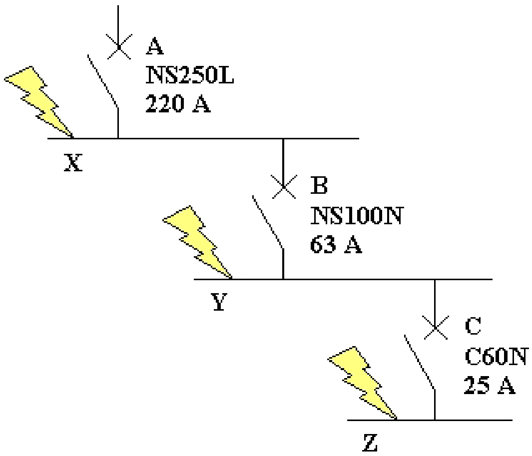


Figure I.42: Selectivity principle

The following choice provides total selectivity from the point of view of overloads and low short circuits.

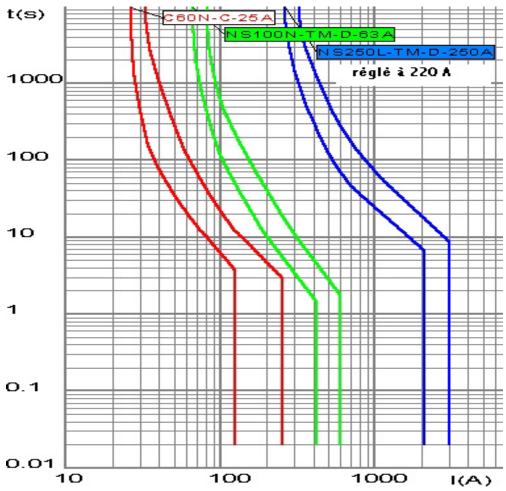


Figure I.43: Circuit breaker curves at points A, B and C

On the other hand, selectivity is only partial for high short-circuits. For short circuits at point Z exceeding 500 A, both circuit-breakers B and C may open.

Selectivity is based on several modes, and manufacturers offer 4 modes:

- Amperometric selectivity.
- Chronometric selectivity.
- Logic selectivity (reserved for circuit-breakers equipped with logic modules).
- Energy selectivity (reserved for high currents and circuit-breakers equipped with limiter modules).

A) **Amperometric selectivity.**

The up stream circuit-breaker has a higher thermal and magnetic setting than the downstream

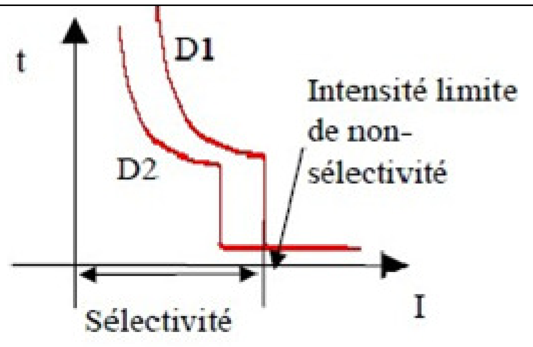


Figure I.44: Amperometric selectivity

Selectivity is ensured if the short-circuit current through the two circuit-breakers remains below the setting of the circuit-breaker's magnetic relay. upstream D1

The up stream circuit-breaker has its magnetic relays slightly delayed compared to those of the downstream circuit-breaker.

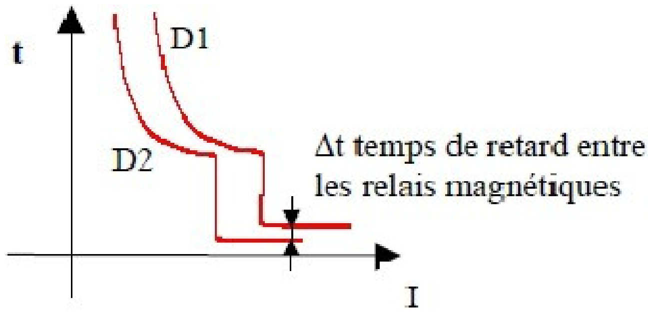


Figure I.45:Chronometric selectivity

In this case, selectivity is guaranteed regardless of the short-circuit current flowing through the two circuit-breakers.

Two circuit-breakers are said to be selective: if the curve of the upstream circuit-breaker is at the top right of the curve of the downstream circuit-breaker.

Parentage

Wiring is a combination technique that uses the limiting capacity of circuit-breakers to install circuit-breakers with reduced breaking capacity downstream, thereby reducing installation costs.

Example: 3 circuit-breakers A,B,C are in series. The assumed short-circuit currents are 80kA downstream of A, 50 kA downstream of B, 24 kA downstream of C.

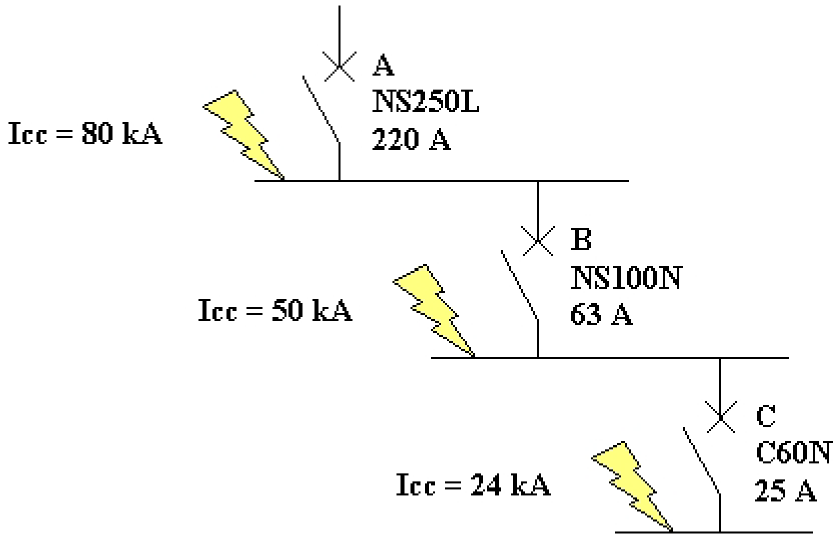


Figure I.46: Principle of filiation [4].

The following table shows that the C60N alone has a breaking capacity of 10 kA. Its breaking capacity increases when combined with an NS100N (25 kA) or an NS250L (30 kA). It therefore has a breaking capacity of 30 kA (higher than 24 kA). The NS100N alone has insufficient breaking capacity (25 kA), but combined with the NS250L, its breaking capacity rises to 150 kA (greater than 50 kA).

Mains 400v-415v						
Upstream PdC (kAeff)		C60N	NSA160N	NS100N	NS160H	NS250L
		10	30	25	70	150
Down stream Pdc (kAeff) (filiation)	C60N	-	25	25	30	30
	NG125N	-	-	-	50	70
	NS100N	-	-	-	70	150

8. Active and passive sensors

A sensor is a component that transforms a physical quantity (position, temperature, brightness, etc.) into a generally electrical quantity.

a) Active sensor: based on a source that produces an electrical signal translating the measurand as faithfully as possible. The output "*s*" is a:

- load
- voltage
- current

- **Thermo electric effect**

A circuit made up of 2 chemically different conductors whose junctions J1 and J2 are at different temperatures (T1 and T2) induces an electromotive force (emf) proportional to the temperature difference.

E.g.: Thermocouple

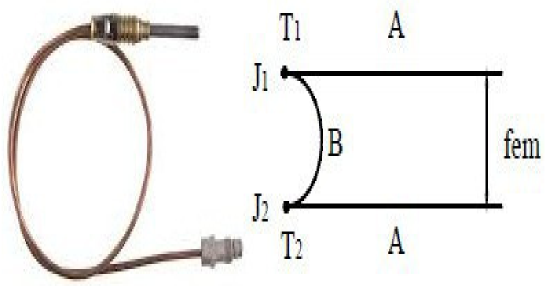


Figure I.47: Thermocouple sensor

- **Pyroelectric effects**

Spontaneous electrical polarization of certain crystals (e.g. triglycine sulfate), depending on their temperature. They carry electrical charges on the surface proportional to this polarization and of opposite signs on the 2 faces. *Φ* : luminous radiation flux

V: voltage variation across an associated capacitor

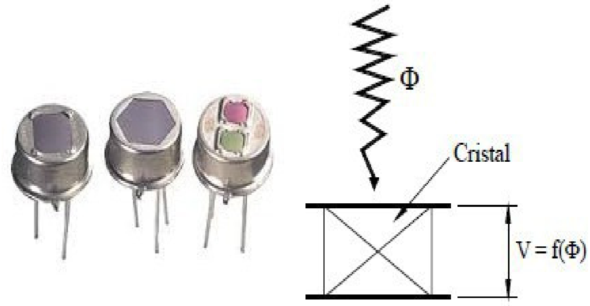


Figure I.48: Pyroelectric sensor

- **Piezoelectric effects**:

Applying mechanical stress to certain materials (e.g. quartz crystals) causes deformation that creates equal and opposite electrical charges on the faces under load.

F:compressive force

V:voltage variation across an associated capacitor

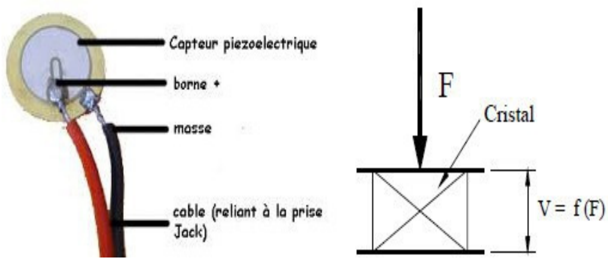


Figure I.49: Piezoelectric sensor

- **Electromagnetic induction**:

When a conductor moves in a fixed induction field, it generates an emf proportional to the flux cut off per unit of time, i.e. toits speed of travel. Ω: frame rotation

B: fixed induction

V : fem created

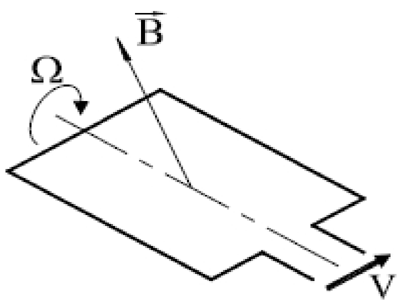


Figure I.50: Electromagnetic induction

- **Hall effects**:

- When a material semiconductor material is flowed through by a current *I*

I The real source of signal energy is the current *I*.

$$V = K_H \, I \, B \sin\theta$$

K_H: depends on semiconductor material and dimensions forming an angle θ with the current, a voltage *V* appears in the material perpendicular to *B* and to and subjected to an induction *B* (magnetic field).

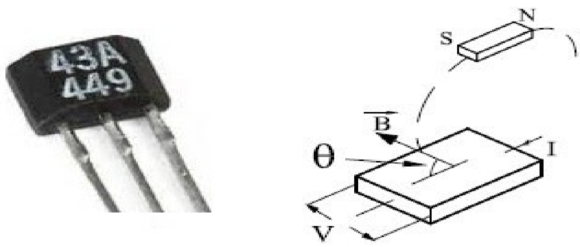


Figure I.51: Hall-effect sensor

b) Passive sensor: based on an impedance whose variation reflects the measurand and which can only be measured by an appropriate circuit (conditioner) powered by an external source. The output "s" is a:

- resistance
- inductance
- capacity

These are generally impedance sensors, one of whose determining parameters is sensitive to the variable being measured. Table I.4 summarizes the characteristic parameters for each type of passive sensor.

Table I.4: Passive sensors and their sensitive electrical characteristics

Measurand	Sensitive electrical characteristics	Materials used
Temperature Very low temperature	Resistivity, ρ Dielectric constant, ε	Platinum, nickel, copper, Semiconductors, Glass
Optical radiation flux	Resistivity, ρ	Semiconductors
Deformation	Resistivity, ρ Magnetic permeability, μ	Nickel alloy, doped silicon Ferromagnetic alloys
Position (magnet)	Resistivity, ρ	Materials magneto resistant materials: bismuth, indium antimonide
Humidity	Resistivity, ρ Dielectric constant, ε	Lithium chloride Alumina, polymer
Level	Dielectric constant, ε	Insulating liquids

- **Photo resistance LDR**

For certain materials, the resistivity ρ depends on the luminous flux incident on the material: this is the photo resistive effect. The LDR (Light Dependent Resistor) has a resistance that varies as a function of received light intensity: this is very high in the dark (from 1 to 100 MΩ), then decreases to a few hundred Ohms under intense illumination (e.g. 103 lux).

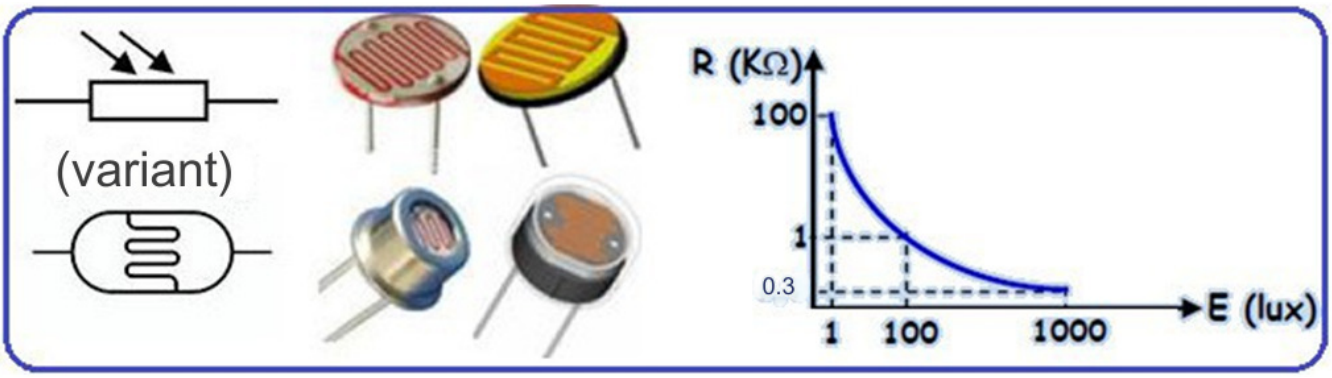


Figure I.52: Photoresistor characteristics resistance variation as a function of luminance E.

- **Thermistors**

Thermistors are semiconductor components.

The nominal resistance value of a thermistor is given for anominal temperature of 25°C. There are two types of thermistors:

□ NTC (Negative Temperature Coefficient) thermistors: the resistance decreases when the temperature rises, and vice versa.

□ PTC (Positive Temperature Coefficient) or PTC thermistors: their resistance increases as the temperature rises, and vice versa.

To translate the measured temperature into an electrical signal, we use, for example, the conditioning circuit shown in figure 4b. This produces a voltage Vs which is the image of the measured temperature

$$V=V_{SCC}.[R_{CTN}/(R_{CTN}+R)]$$

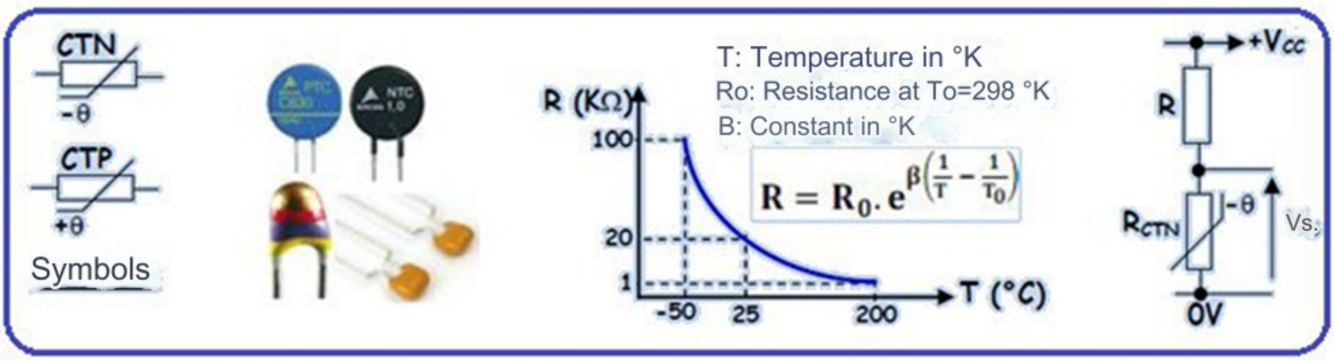


Figure I.53: Thermistor characteristics

-Potentiometric displacement transducers

Potentiometers can be used to create simple sensors for measuring the linear or angular displacement of an object. To achieve this, simply connect the object mechanically to the cursor C of a potentiometer and apply a DC voltage V_{CC} between its ends A and B (conditioner).

Linear potentiometers are used to measure rectilinear displacements (see **Figure I.54**):

$R_1 = R.(L/L_0), R_2 = R.(L-L/L_{00})$ and $V = V_{SCC}.L/L_0 = k.L$

With $k = V/L_{CC0}$: sensor sensitivity in Volt/meter.

Single-turn or multi-turn rotary potentiometers are used to measure angles of rotation

$R_1 = R.(\theta/\theta_0)$, $R2 = R.(\theta - \theta/\theta_{00})$ and $V = V_{SCC}.\theta/\theta_0 = k.\theta$

with : $k = V_{CC}/\theta_0$: sensor sensitivity in Volt/degree.

The major disadvantage of this type of sensor is wear due to mechanical friction,which limits its service life, which is closely linked to the number of maneuvers.

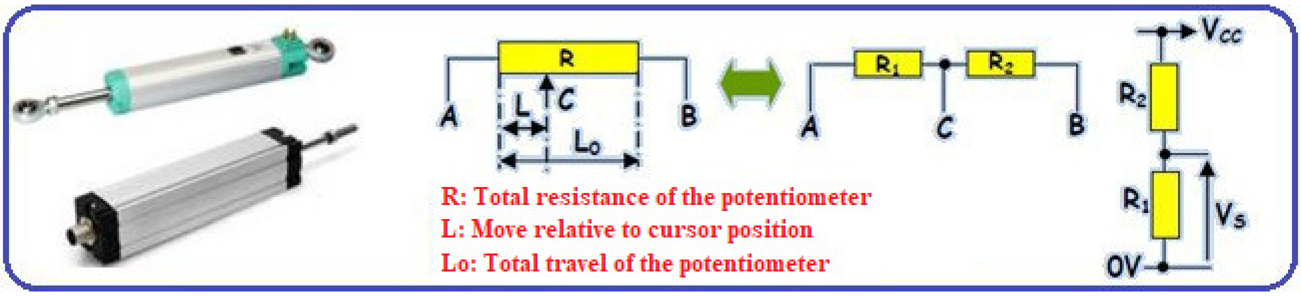


Figure I.54: Displacement potentiometer characteristics

-Sensors based on strain gages

Extensio-metric gauges are used to determine stresses in materials. They are the basis for all kinds of force, torque and pressure transducers.

The strain gage consists of a miniaturized resistive track bonded to an insulating resin support (substrate), which is then bonded to the test body that will undergo the deformation to be measured. The strain gage consists of contiguous coils generally made from a thin metal foil (a few µm thick).

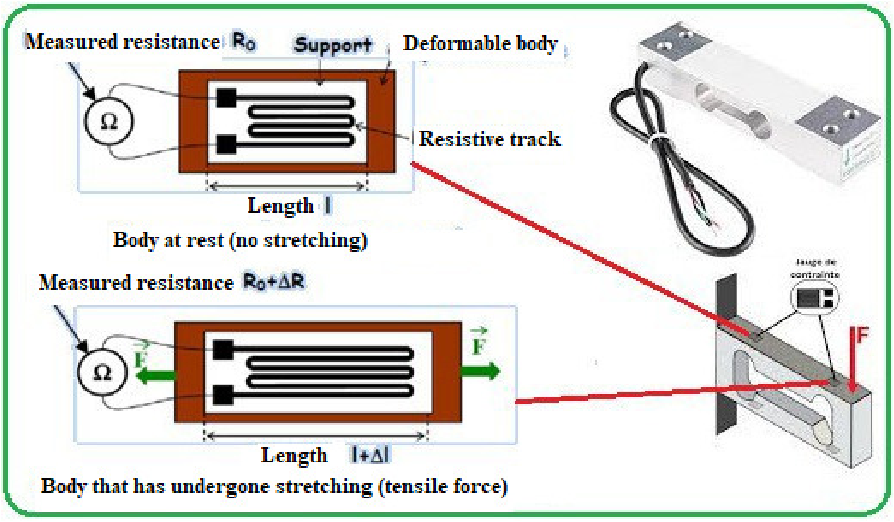


Figure I.55: Strain gage-based sensors

The support and test body must be flexible and elastic.

The resistance of a conductor is given by the relationship R= (ρ.l)/s. Deformation of the conductor (gauge), modifies the length l, resulting in a variation in resistance R.

The general relationship for gauges is $(\Delta R/R_0) = k.(\Delta I/I)$ where k is the gauge factor which depends on the gauge material and temperature, and characterizes the sensitivity of the gauge.

Chapter II: Drawing up electrical diagrams

1. Standard symbols for switchgear electrical.

An electrical diagram uses graphic symbols to show the various parts of a network, installation or piece of equipment that are connected and functionally linked.

The purpose of an electrical diagram is to :

- Explain how the equipment works (may be accompanied by tables and diagrams);
- Provide the basis for drawing up production diagrams;
- Facilitate testing and maintenance.

Electrical symbols are governed by standardized international norms. The trend is towards a common language for electricians, making it easier to write, read and understand electrical diagrams. The various standardization bodies In France, AFNOR (Association Française de NORmalisation) publishes all French standards: mechanical engineering, textiles...

Electrical standardization is handled by UTE(Union Technique des Electriciens), and in Europe by CENELEC (Comité Européen de Normalisation Electrique).

2. Classification of graphic symbol standards for diagrams in accordance with NF C 03-xxx

NFC 03-201: General,general index.Correspondence tables

NF C 03-202: of symbols, distinctive symbols and other symbols of general application NF C 03-203: Conducteurs et dispositifs de liaison

NFC 03-204: Basic passive components

NFC 03-205: Semiconductors and electronic tubes

NF C 03-206: Production, transformation et conversion de l'énergie électrique NF C 03-207: Apparatus and control and protection devices

NFC 03-208: Measuring instruments, lamps and signaling devices

NF C 03-209: Telecommunications: Switching, peripheral equipment NF C 03-210: Telecommunications: Transmission

NF C 03-211: Installation, architectural and topographical diagrams and drawings NF C 03-212: Binary logic operators

NFC 03-213: Analog operators

Electric motors

	General symbol (replace with a machine designation letter)		Single-phase asynchronous motor with split phase		Permanent Magnet DC Motor
	Stepper motor		Three-phase asynchronous motor with short-circuited rotor		Series-excited DC motor

Contacts

	Closing contact (working contact) (NO)		Two-way contact without overlap		Delayed closing contact at work (NO)
	Break contact (rest contact) (NC)		Two-position contact with middle opening position		Delayed opening contact at rest (NC)
	Manually operated closing contact (NO)		Self-closing push button with automatic return (NO)		Rotary button with automatic closing without return (NO)
	Temperature-controlled closing (NO) switch		Temperature-controlled opening (NC) switch		Contact of a thermal relay (NC)
	Contact of a circuit breaker		Contact of a disconnector switch		Contactor
	Contact of a disconnector		Contact of an automatic opening disconnector switch		Contact of a disconnecting fuse
	Contact of a fuse switch disconnector		Proximity sensitive sensor with closing contact		Proximity sensitive device, controlled with a magnet, with a closing contact

NO: Normally opened normally open NC: Normally closed normally closed (NC)

Control organ (relay coil)

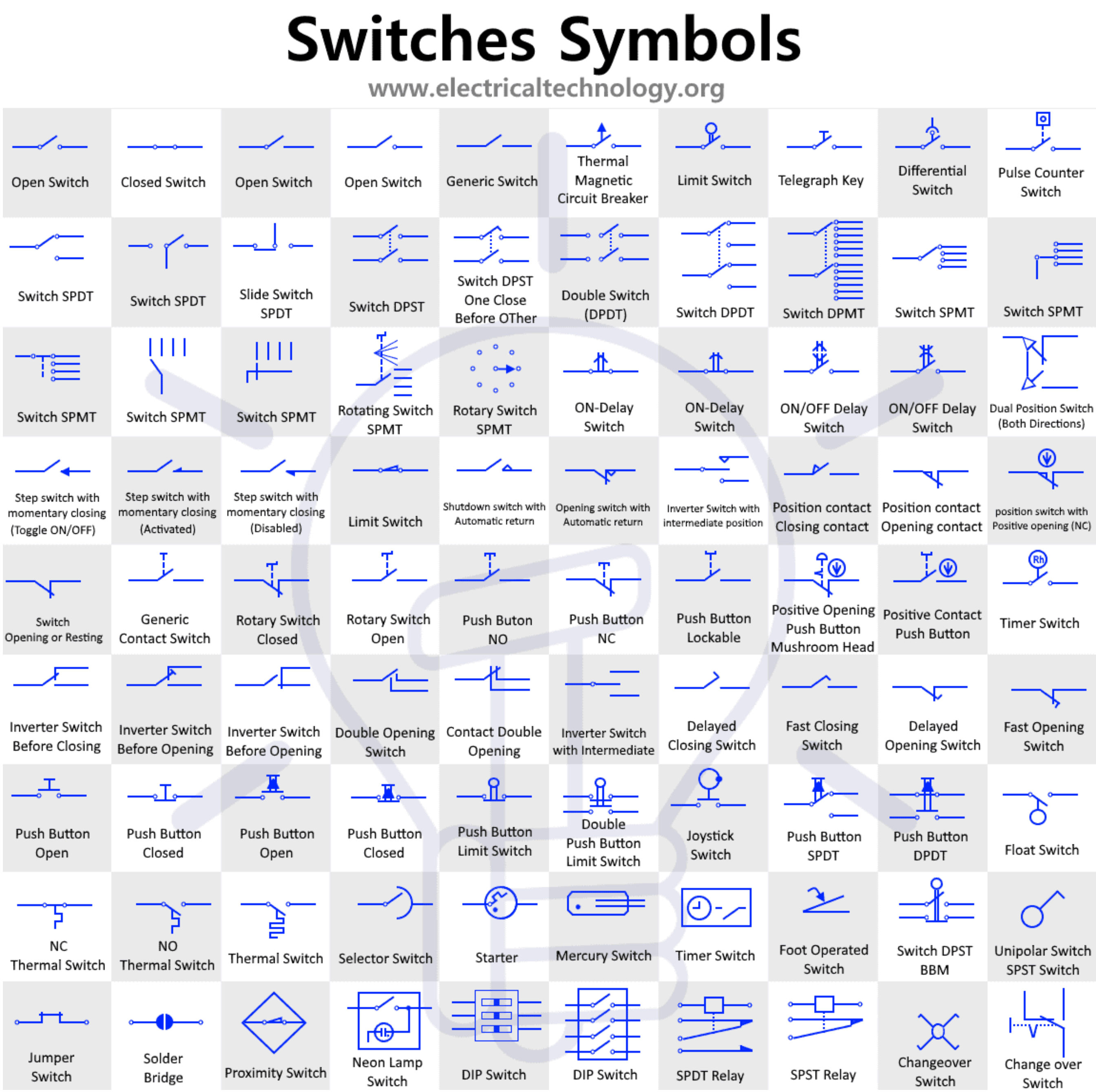
	Control organ of a relay (general symbol)		Control organ of a mechanically interlocked relay		Control unit of a thermal relay

Measuring devices

	Ideal voltage generator		Ideal current generator		Wattmeter
	Voltmeter		Frequency meter		Phase meter
	Ammeter		Oscilloscope		Tachometer

Miscellaneous

	Fuse (general symbol)		Sensor sensitive to a proximity		Indicator light



3. Classification of diagrams according to representation mode

There are several ways of representing an electrical circuit. Each of these forms of representation, called a schematic, reveals much the same information. However, each one highlights the elements essential to the needs of different users in different situations. Electrical diagrams are classified according to their field of application for example define **two families** of diagrams for installations in the **domestic sector** and the industrial sector.

4. Industrial sector.

4.1 Electrical diagrams for the home: everything to do with the building (distribution, lighting, heating, alarm, telephone, etc.).

There are 4 types of schematics

a- Diagram developed:

This is the diagram that makes it easy to understand how an electrical installation works. It does not take into account the location of the switchgear. This is the diagram used for study and design. All elements are arranged in a straight line between 2 supply wires.

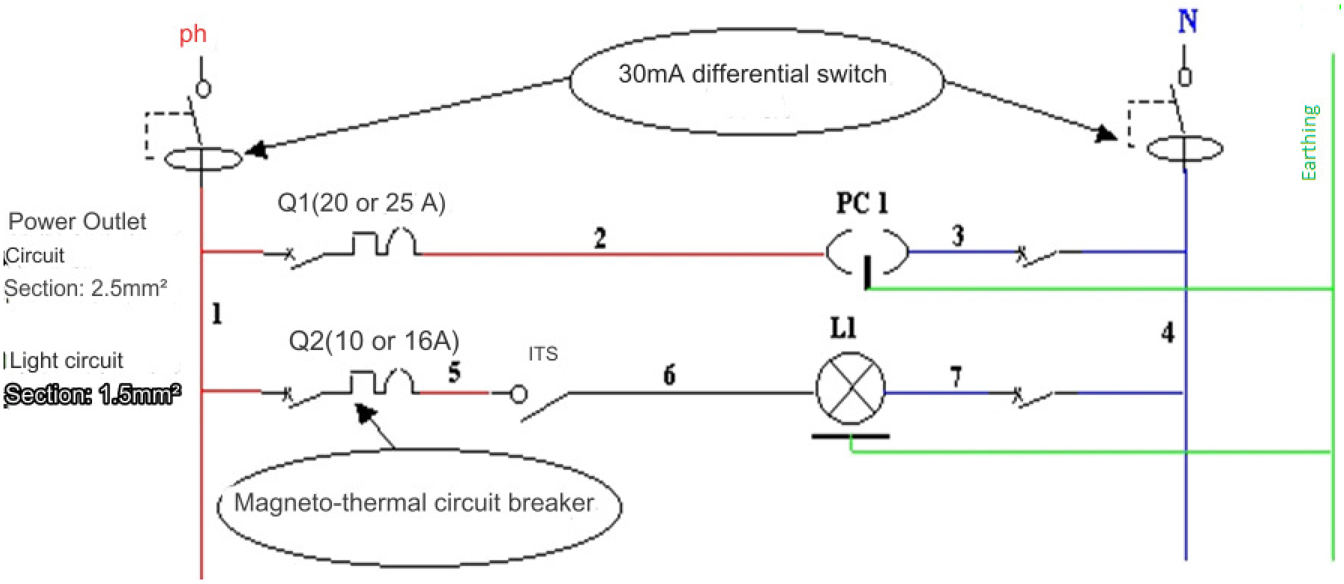


Figure II.1: An example of a developed diagram

b- Architectural diagram :

This is the diagram designed by an architect. It positions the devices in the space and indicates the links between the control points (switch) and the controlled device (lamp) using dotted lines. This architectural diagram, designed by an architect, shows where to locate lamps, switches, lighting, sockets, thermostats, electric heaters, etc.

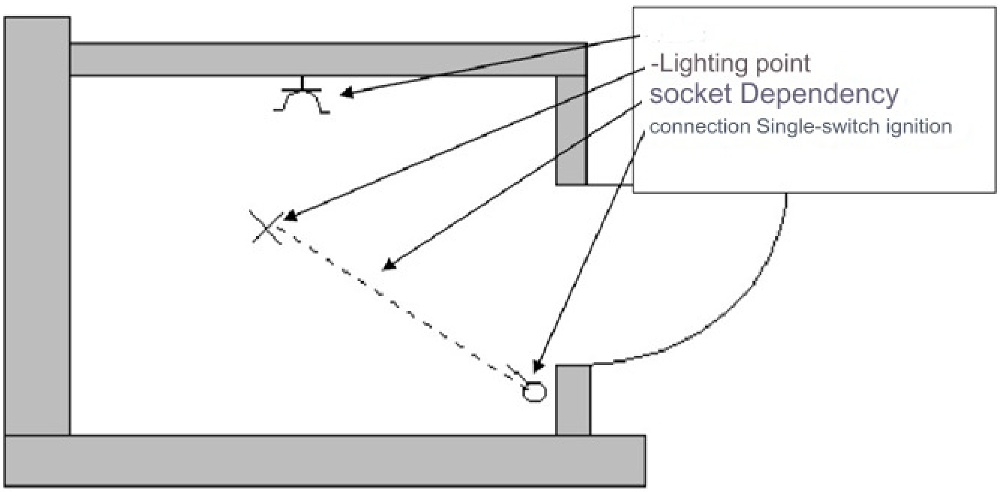


Figure II.2: An example of an architectural diagram

c- Single-line diagram:

This diagram shows the location of electrical conduits. It indicates the number of conductors in each conduit. To create it, you need to refer to the layout or architectural diagram.

It uses the same symbols as the layout or architectural drawing.

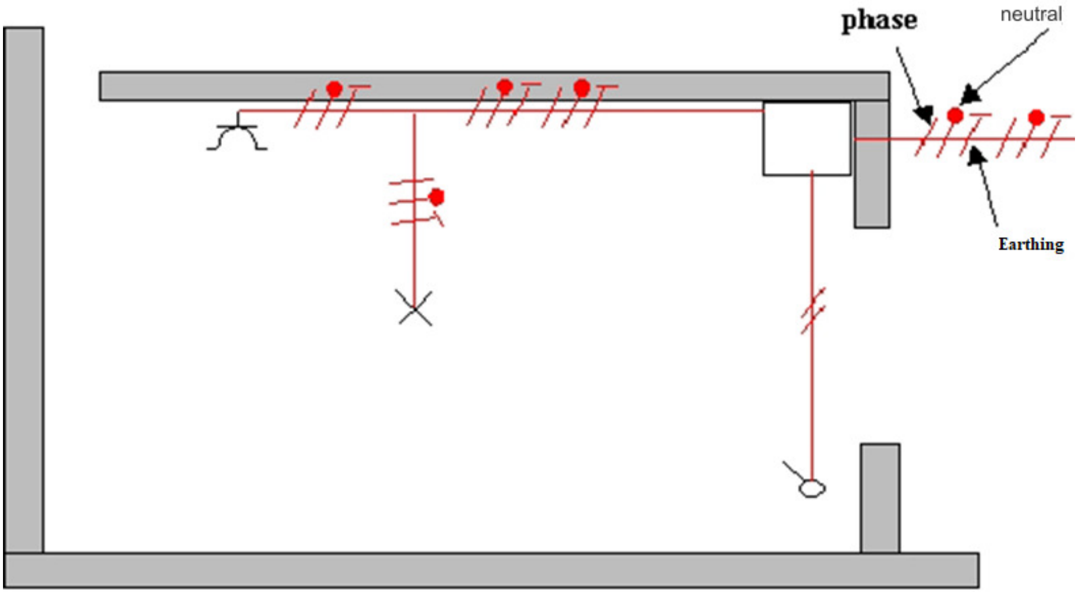


Figure II.3: Unfilar diagram

d- Multi wire diagram :

This diagram represents all the electrical conductors and is based on the single-line diagram for the location of electrical conduits and switchgear. It uses the symbols of the developed diagram and its equipotential marking.

This diagram becomes illegible for complex installations.

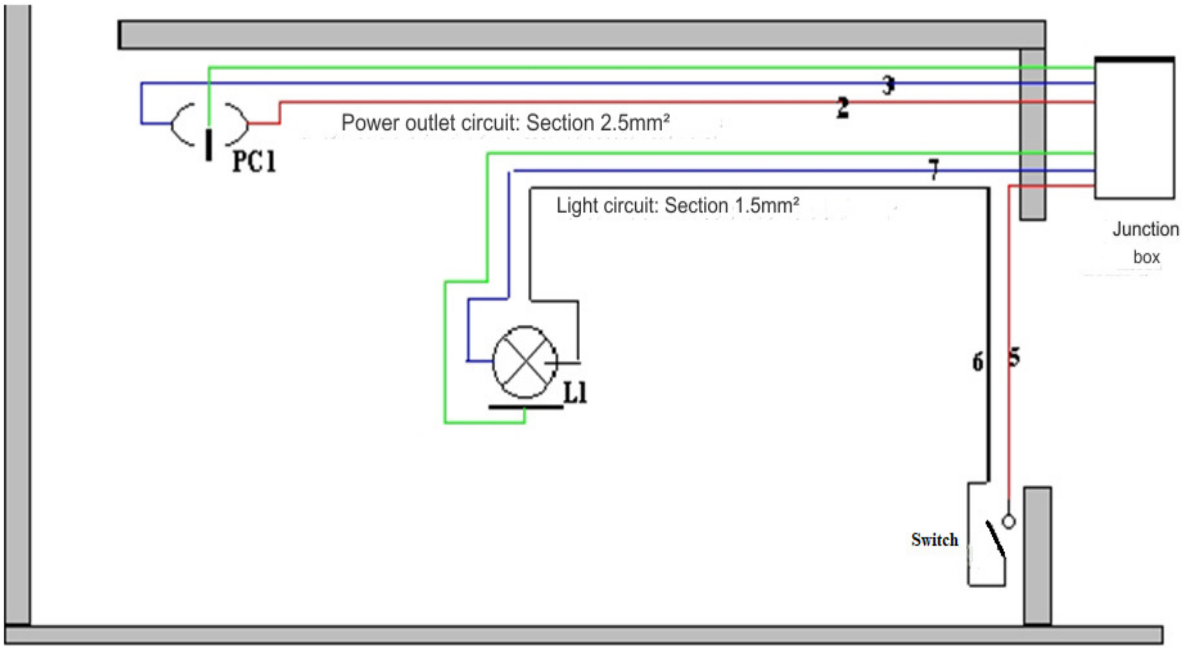


Figure II.4: Multi-wire diagram

4.2 Electrical diagrams in the industrial sector: This concerns the machines or automated systems installed.

In this section we will study and analyze the basic concepts applied to electrical diagrams dedicated to the industrial field.

Or direct starting of an induction motor in two directions of rotation.

e- Diagram developed:

The developed or principle diagrams of this type of starter are made up of two types of circuits which are :

- Control circuit.
- Power circuit.

If a problem a rises when checking the electrical circuits of a domestic or industrial electrical installation, it's easiest to refer to the developed diagram.

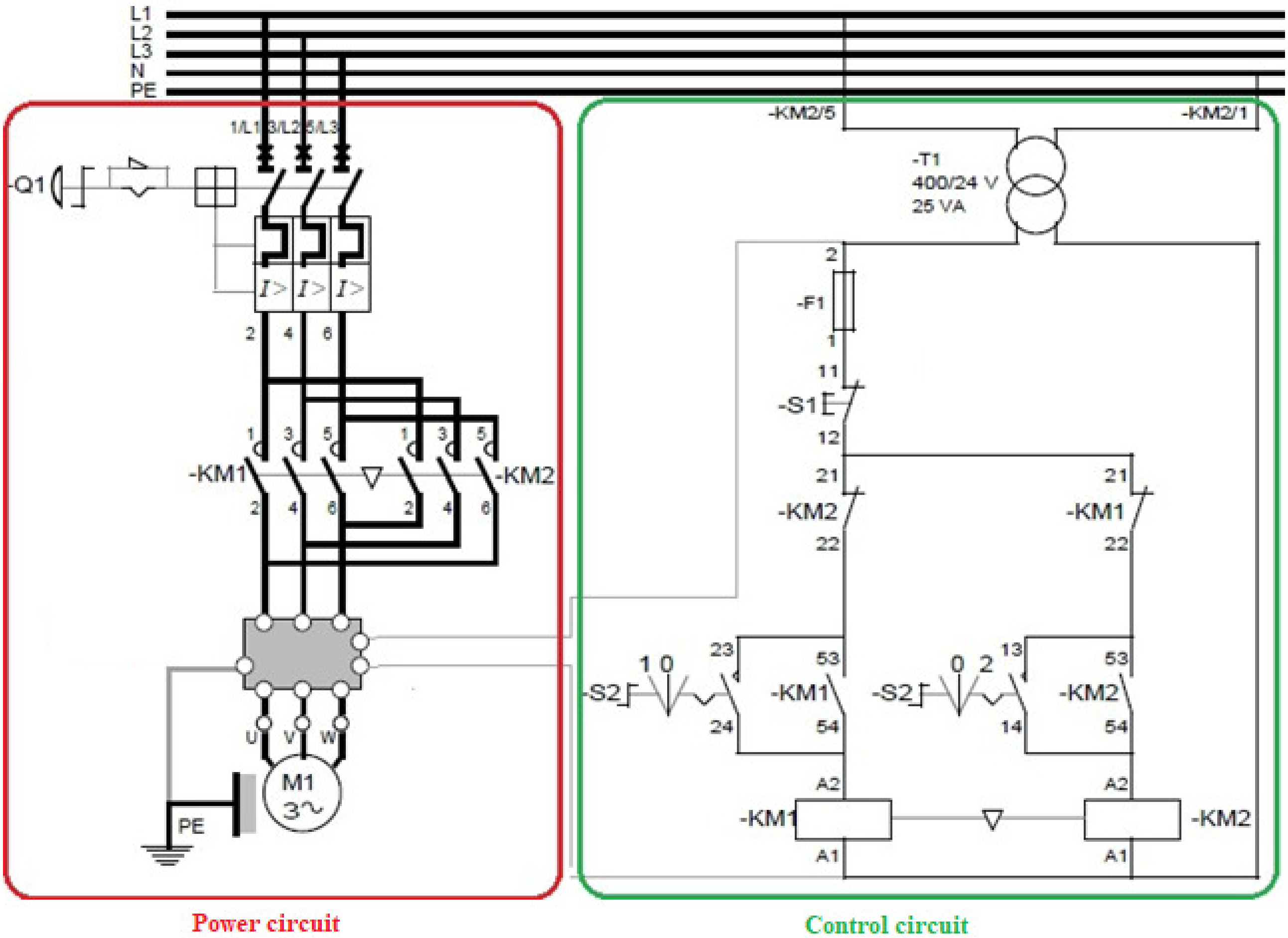


Figure II.5: An example of an industrial diagram(soft start of an induction motor)

f- Block diagram:

The block diagram is a rudimentary method of representation, using a set of rectangles or blocks connected by arrows. Each block includes a short description of its function. The direction of the arrows represents the direction of electrical power or information.

The purpose of a block diagram is to give a brief overview of how a circuit works.

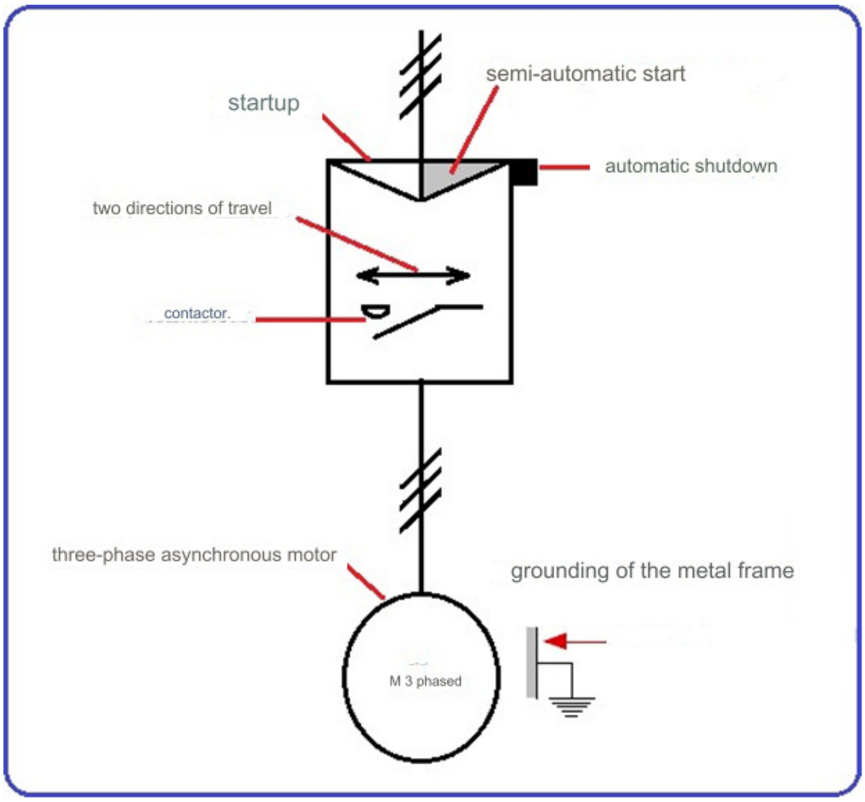


Figure II.6: An example of an industrial block diagram

This type of diagram is mainly used when designing an electrical circuit at the project stage. The rectangles represent the task to be carried out, but do not identify the technology to be used.

g- Single-line diagram:

One-line diagrams in the industrial sector generally illustrate details that are not cumbersome to read or analyze.

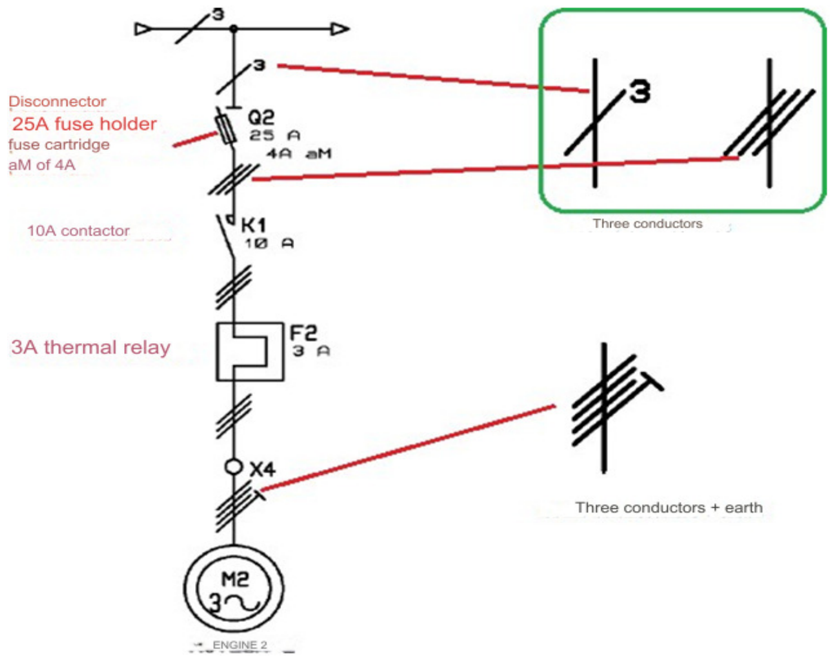


Figure II.7: Single-line diagram of the starting power circuit of an induction motor

h- Multi wire diagram :

The single-wire diagram in the previous paragraph can be represented by the following multi-wire diagram:

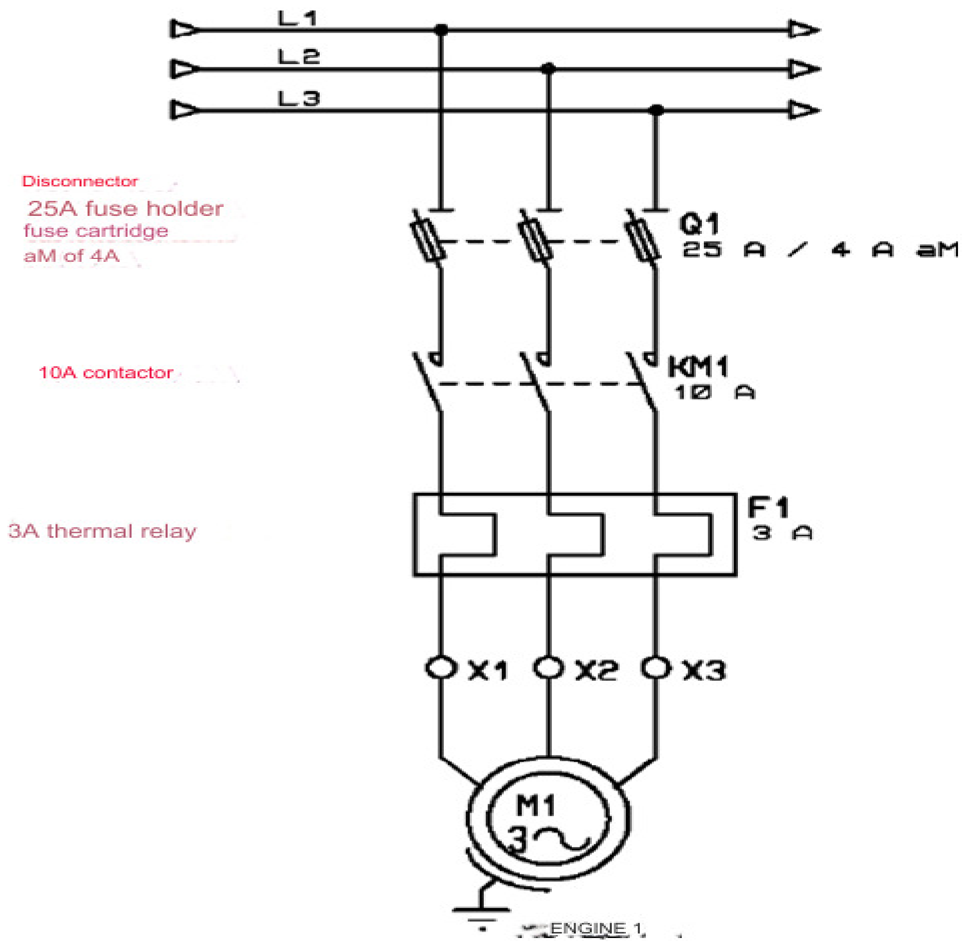


Figure II.8: An example of a multi-wire diagram of the starting power circuit of an induction motor

1. Simple installation ignition

It can be used to establish or interrupt an electric lighting circuit from a single location using a single control device (single-pole switch).

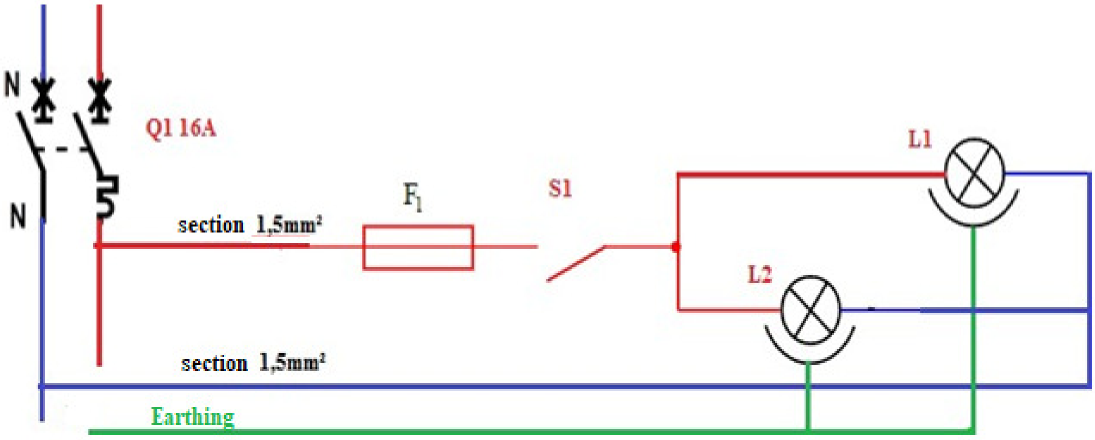


Figure III.1: Developed diagram of a single-ignition circuit

The chronogram corresponding to the single-ignition circuit is illustrated as follows:

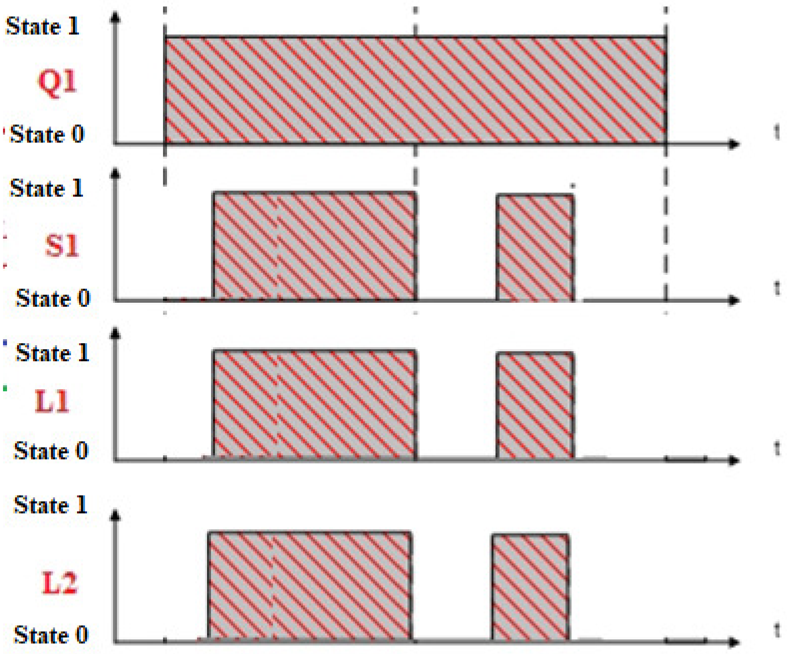


Figure III.2: Timing diagram of a single-ignition circuit

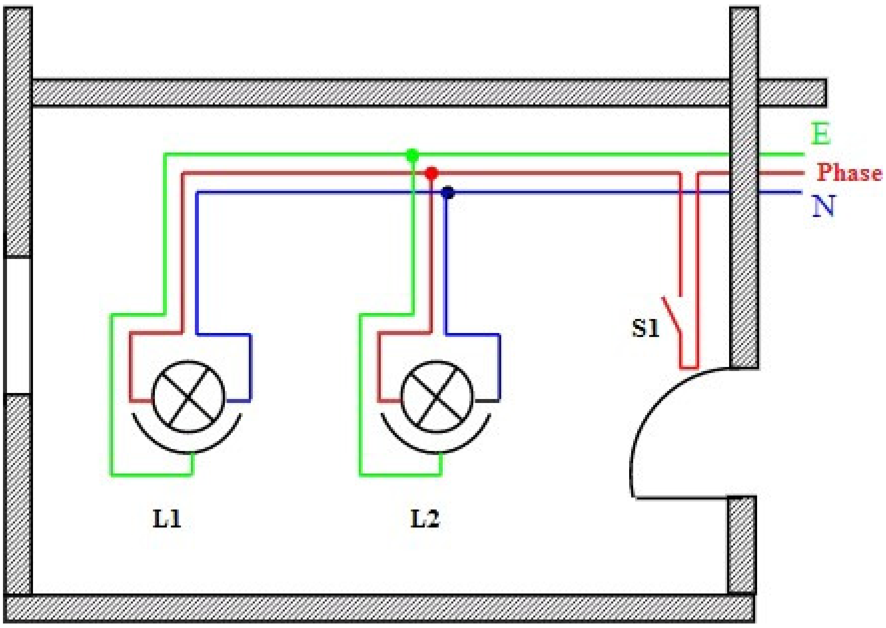


Figure III.3: Multi-wire diagram of a single-ignition circuit

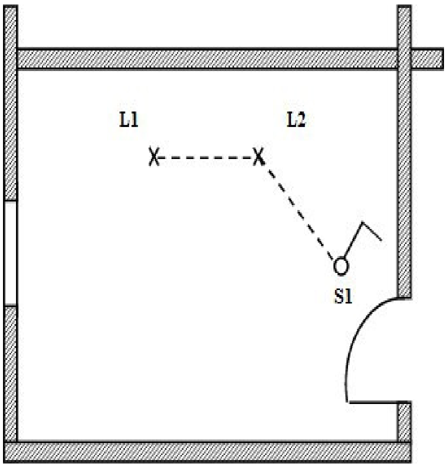


Figure III.4: Architectural diagram of a single-ignition assembly

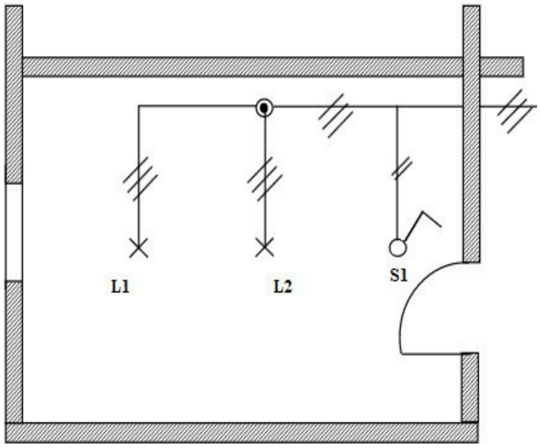


Figure III.5: Single-line diagram of a single-ignition assembly

2. Dual mounting ignition

It allows two different electrical circuits to be established or interrupted from a single location by means of a control device (bipolar switch).

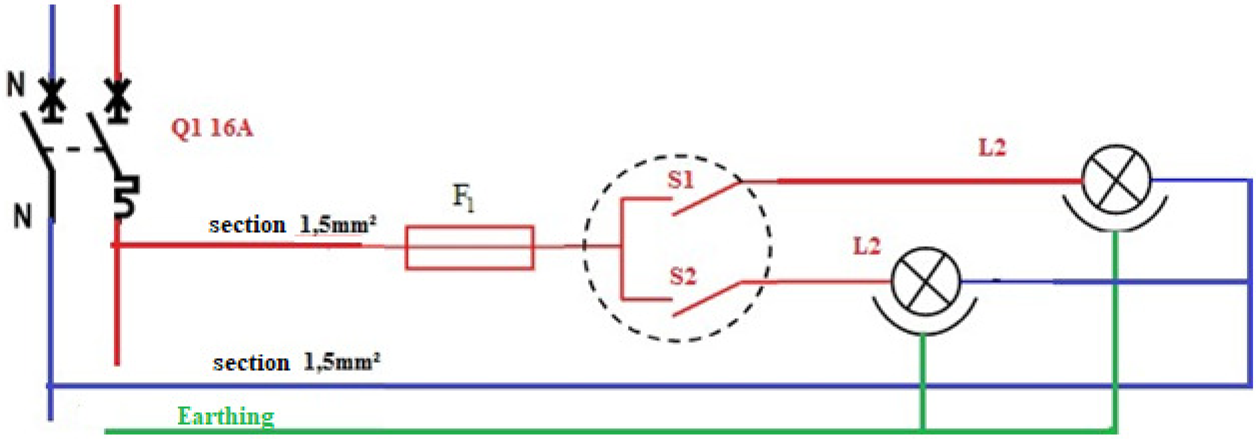


Figure III.6: Developed diagram of a dual ignition circuit

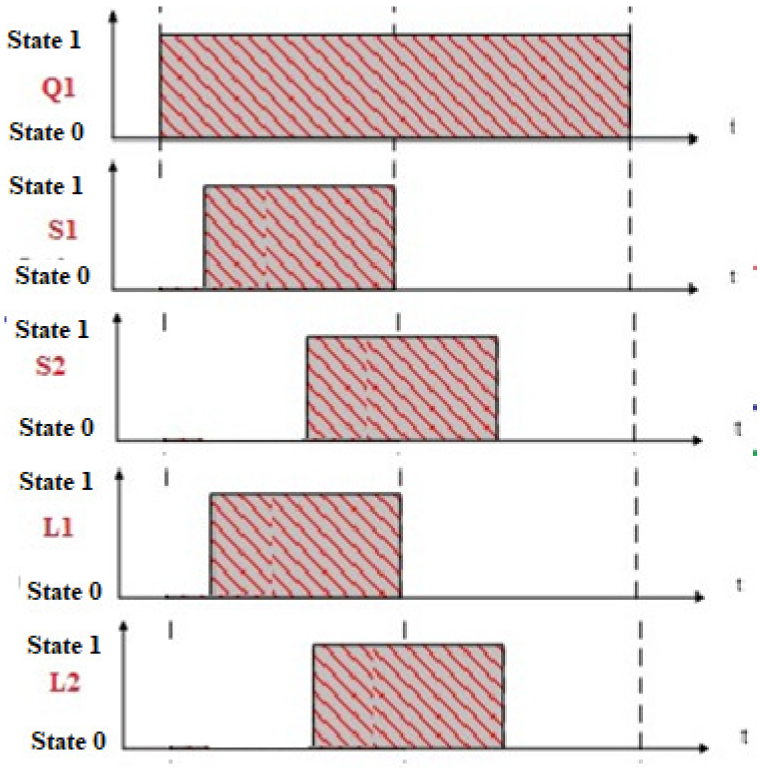


Figure III.7: Chronogram of a dual ignition assembly

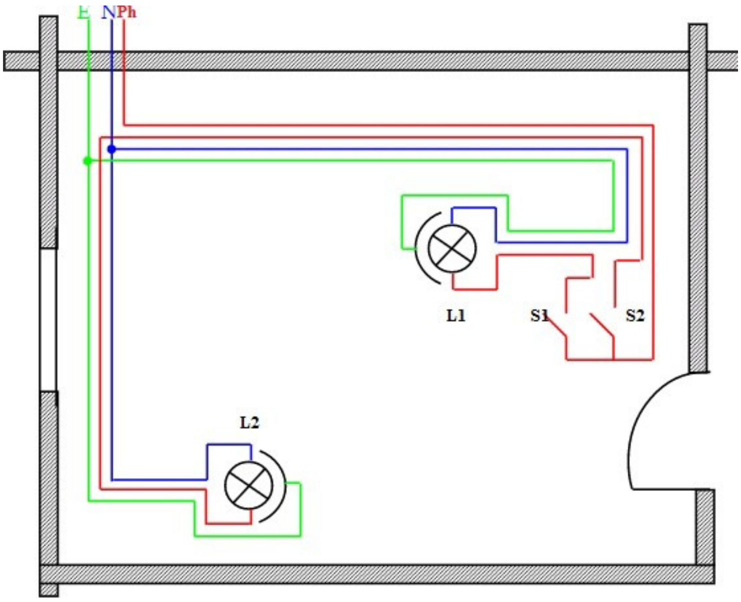


Figure III.8: Dual ignition multi wire diagram

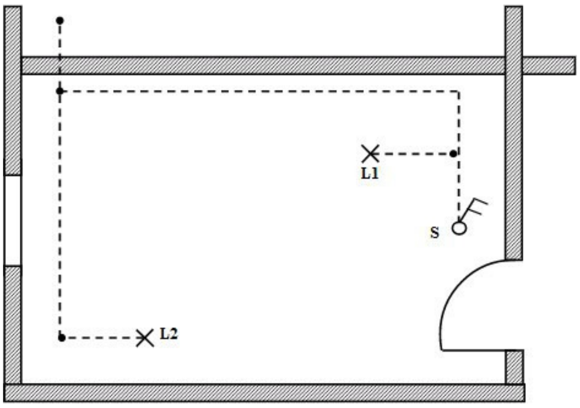


Figure III.9: Dual ignition architectural diagram

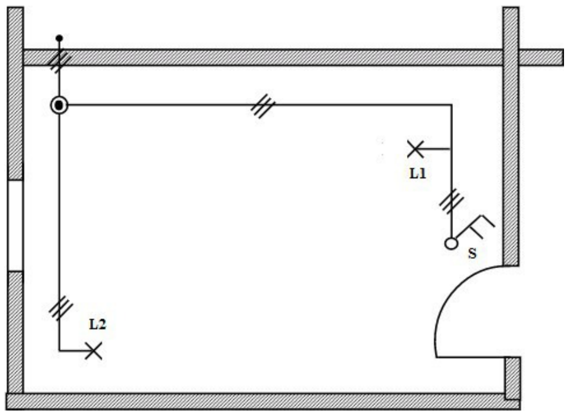


Figure III.10: Single-line dual ignition diagram

3. back-and-forth assembly

The back-and-forth switch is used to energize one or more lighting points from two different locations. The principle of the mechanism is based on the switching of a contact. This contact directs the voltage to two terminals. Depending on its position, one of these two terminals is energized or de-energized. This is the to-and-fro principle. Lighting control devices must be mounted at least 1,10 m above the finished floor. This is approximately the height of door handles. The control box should be positioned opposite the door hinges.

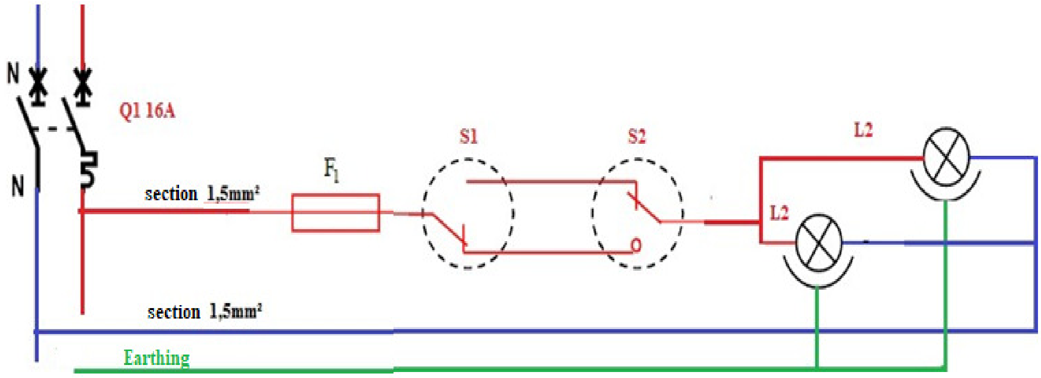


Figure III.11: Schematic diagram of a reciprocating circuit

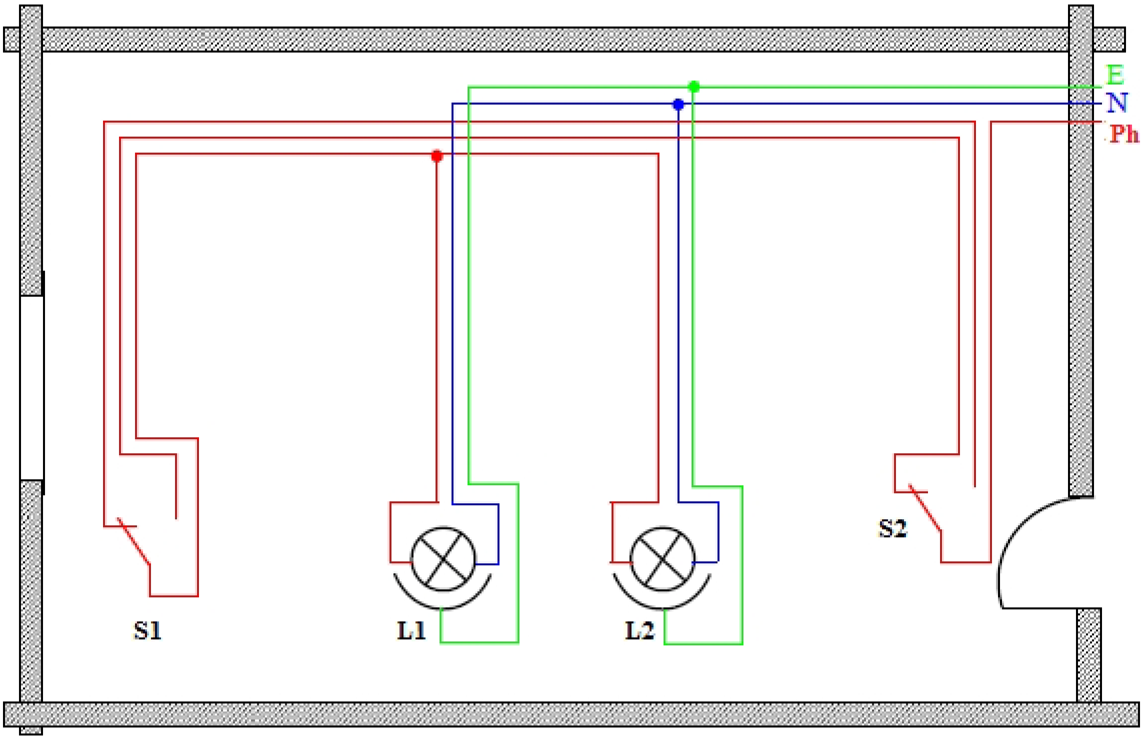


Figure III.12: Multifilament diagram of a back-and-forth circuit

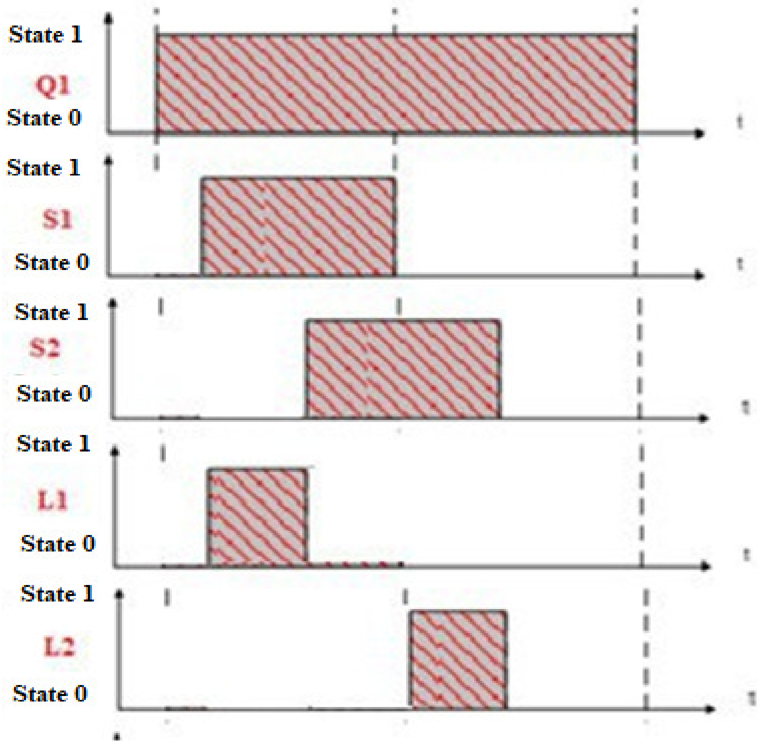


Figure III.13: Timing diagram of a back-and-forth circuit

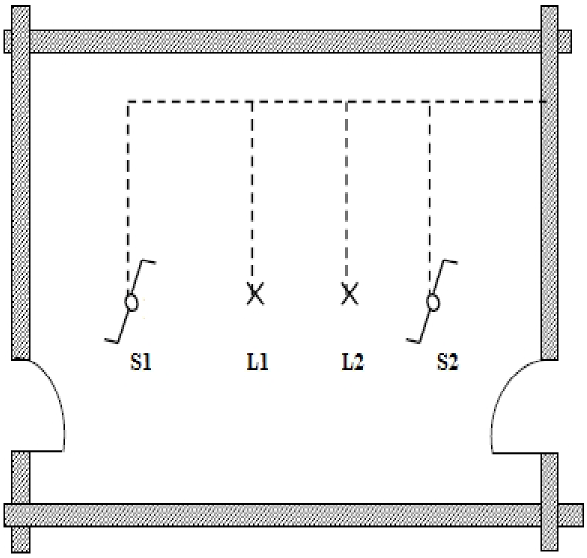


Figure III.14: Architectural diagram of a back-and-forth circuit

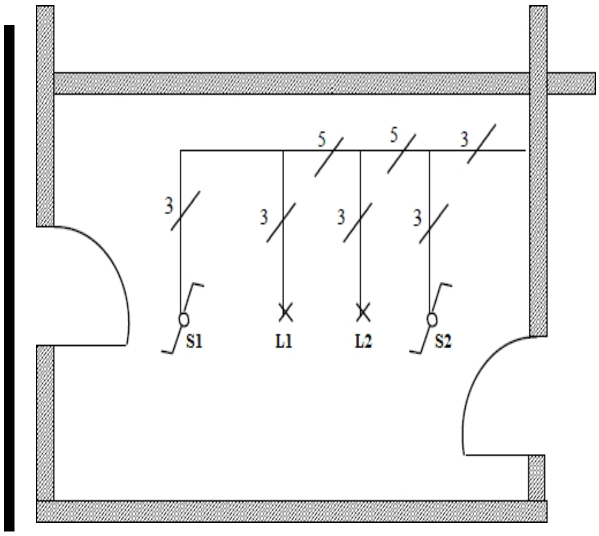


Figure III.15: One-line diagram of a back-and-forth circuit

4. Installation with remote switch for lighting control:

The remote control switch enables a lighting circuit to be controlled by one or more pushbuttons. The remote switch is very practical and economical when you need to install more than three lighting control points, or when the distance between two control points is too great. Examples: long corridor, stairwell, large room...

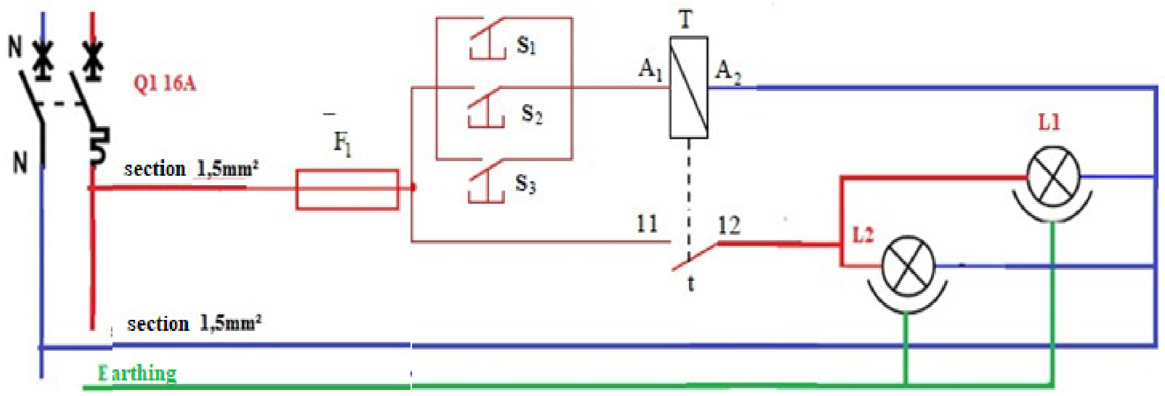


Figure III.16: Schematic diagram of a remote switch assembly

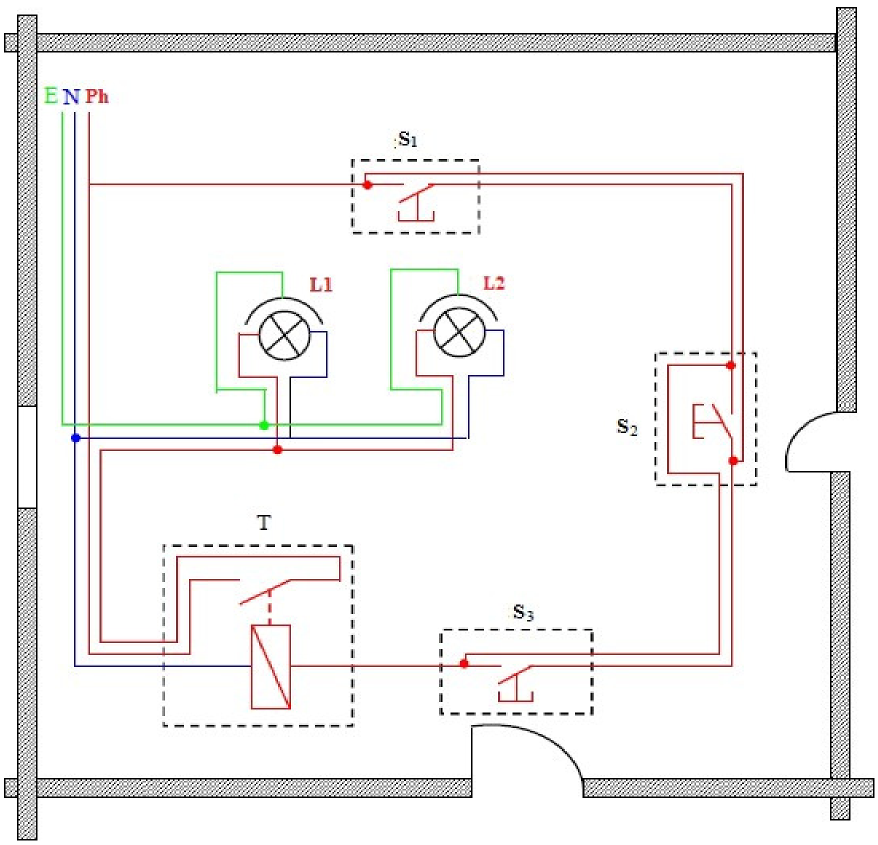


Figure III.17: Multi-wire diagram for remote switch assembly

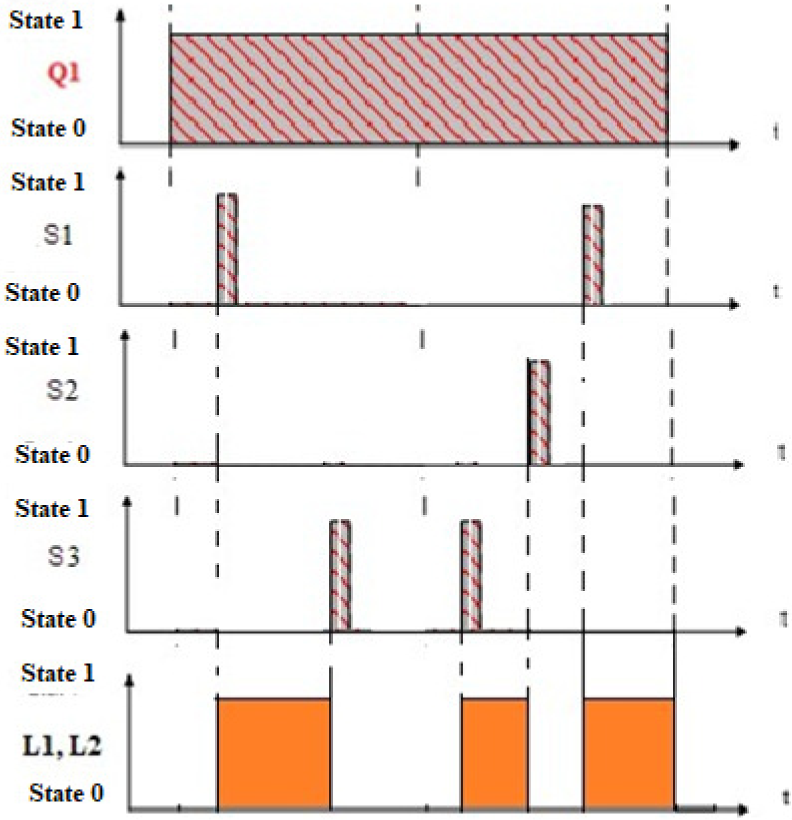
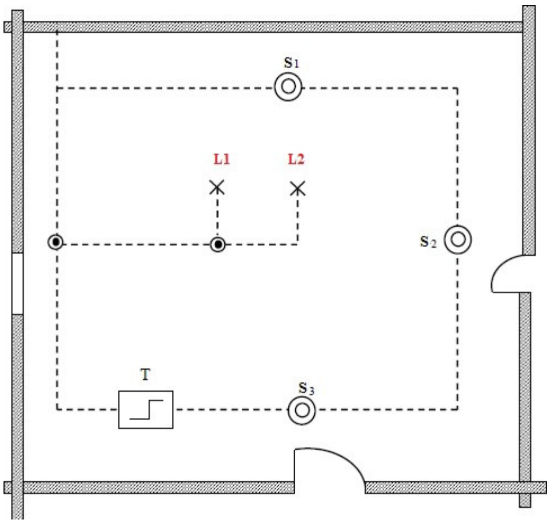


Figure III.18: Timing diagram for remote switch assembly



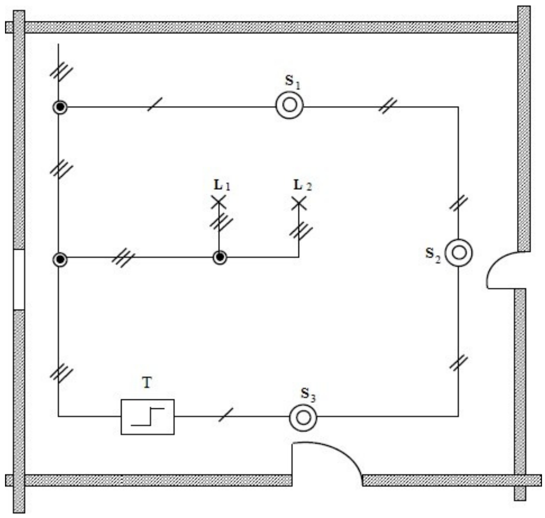


Figure III.19: Architectural diagram of remote switch assembly

Figure III.20: Single-line diagram of remote switch assembly

5. Timer ignition

A timer is an electrical device with a memory, consisting of a coil and one or more contacts. It can be electronic (analog or digital). It can be based on a programmable electrical integrated circuit (microcontroller, FPGA, etc.). It enables a lighting circuit to be controlled by electrical pulses, for any number of locations. It can be switched on manually by pressing one of the push buttons(BP).It is switched off automatically by a timed contact (preset time) with delayed opening.

Assembly with effect: The coil is energized by an impulse on one of the pushbuttons during an operating cycle. If one of these push-buttons is pressed, the timer restarts from that moment on.

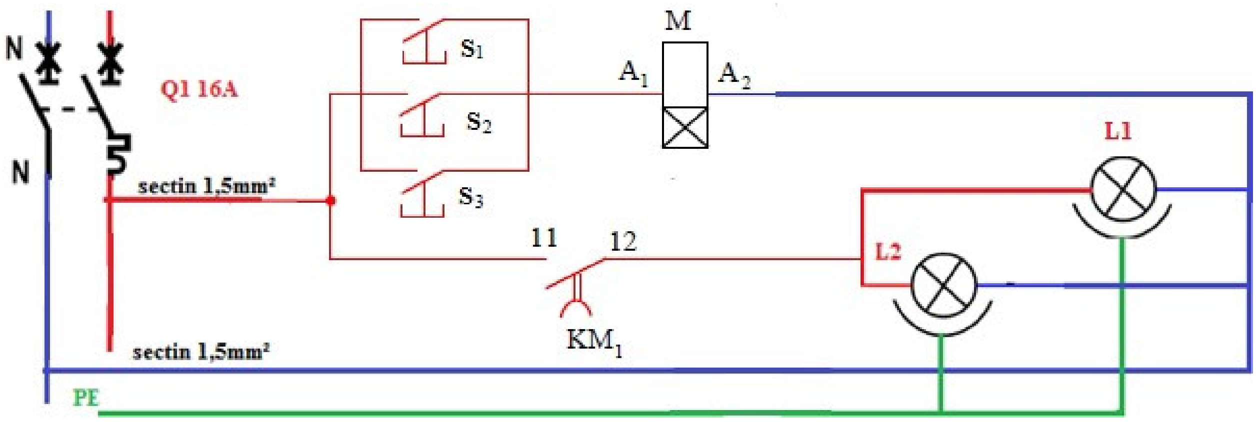


Figure III.21: Schematic diagram of timer circuit with effect

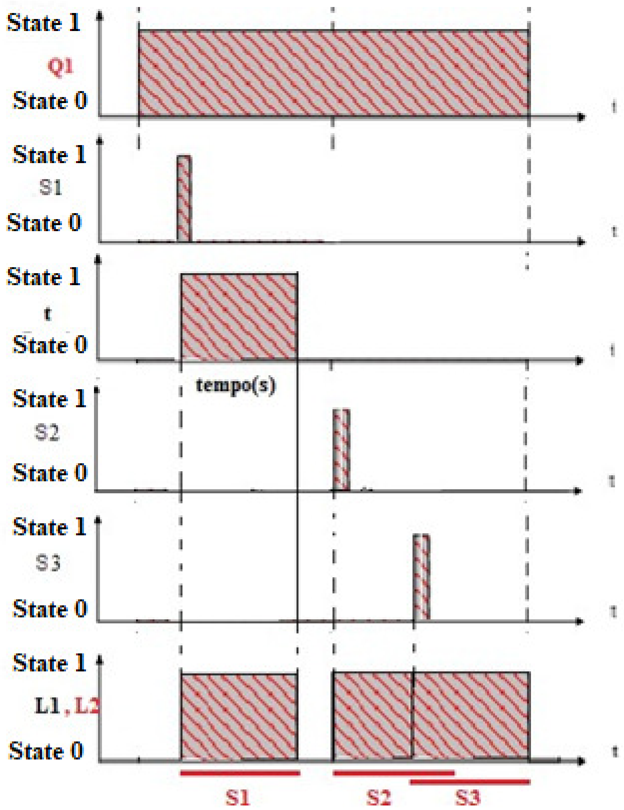


Figure III.22: Timing diagram of a timer with effect assembly

6. **No-effect assembly:** The coil is energized by an impulse on one of the pushbuttons during an operating cycle. If one of the pushbuttons is pressed, the timing remains unchanged and the cycle is not disturbed.

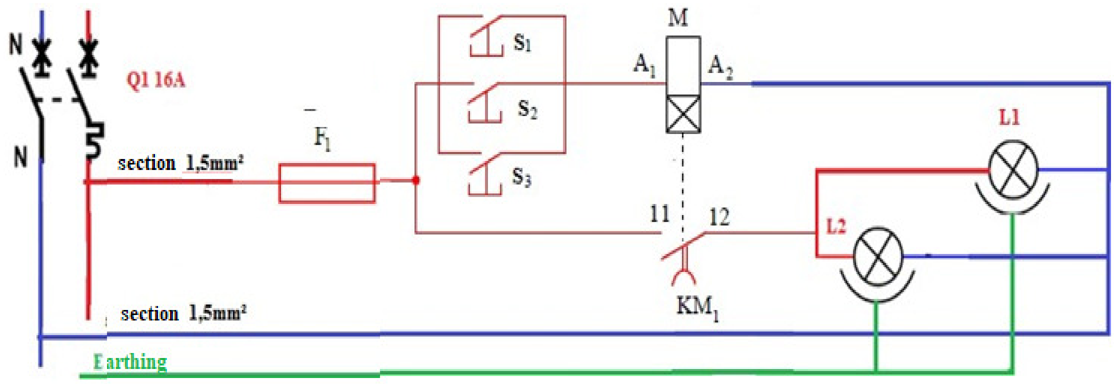


Figure III.23: Timer circuit diagram (no effect)

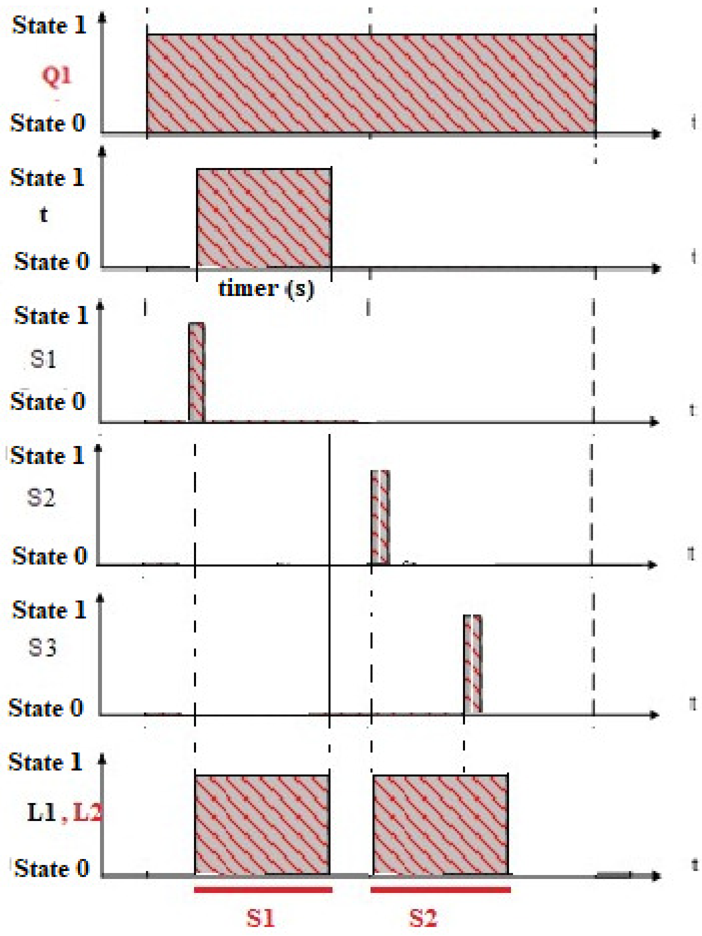


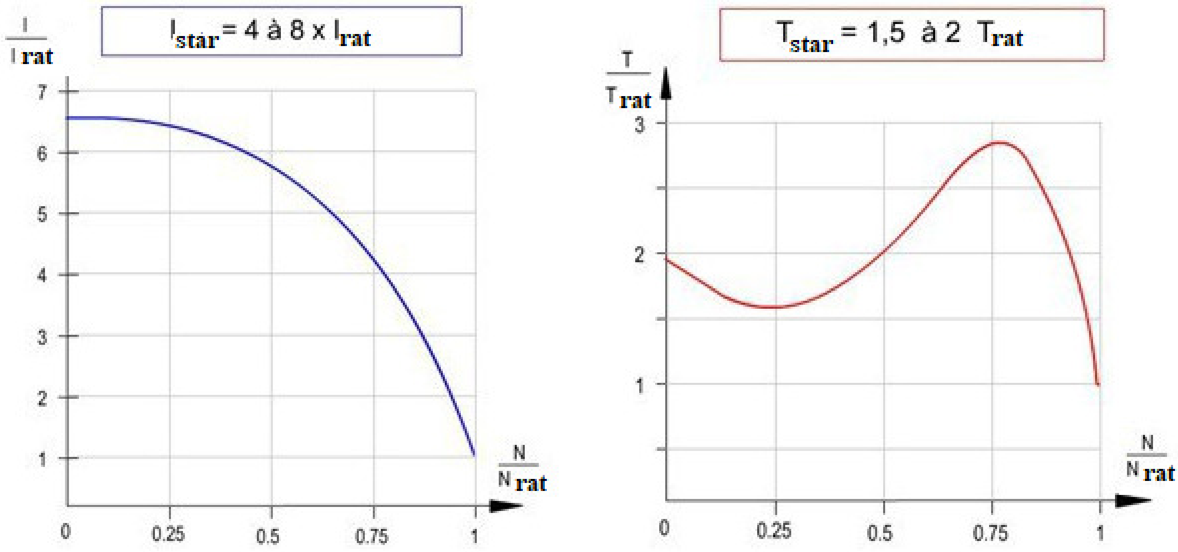
Figure III.24: Timing diagram of a timer with no-effect assembly

Chapter IV: Three control modes for an electric motor

1. Direct-on-Line (DOL) Starting of Induction Motor

Only three-phase asynchronous motors with short-circuited rotor or squirrel-cage rotor can be started directly. When the motor starts, the starting current is around 4 to 8 times the rated current. Take-off torque is very high, at around 1.5 times rated torque.

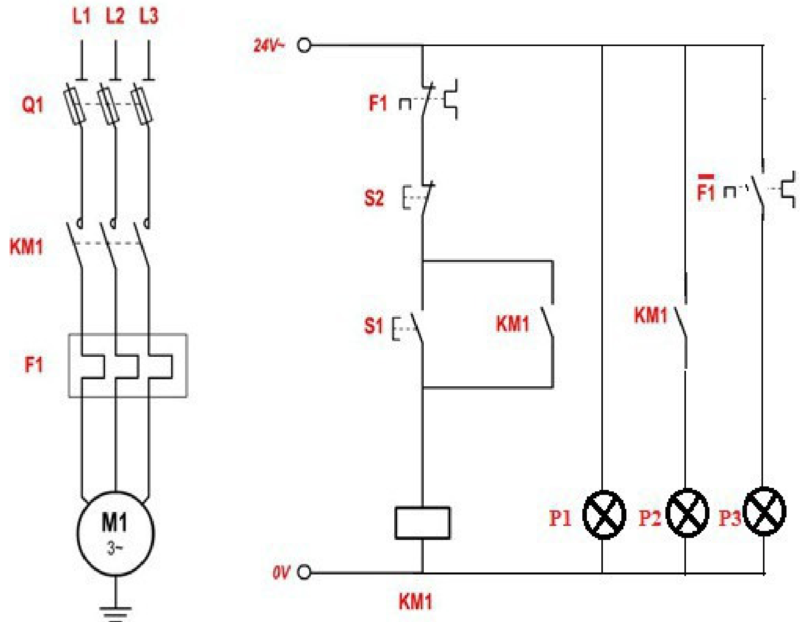
The figure below illustrates the characteristics of a induction motor: *n* is the velocity in revolutions per minute (rpm), T_{rat} is the rated torque, T_{sart} starting torque and I_{rat} is the rated current.



Current characteristics : I = f(n)   Torque characteristics : T = f(n)

Figure IV.1: Current and torque versus speed characteristics of a squirrel cage induction motor.

Explanatory diagrams make it easier to study and understand the operation of a plant or part of a plant. A distinction is made between: A block diagram showing the overall operation of the system, Electrical circuit diagrams provide a detailed understanding of system operation, the equivalence diagram, used to analyze and calculate the characteristics of an electrical circuit. Consider the following control and power diagram for a three phase motor:



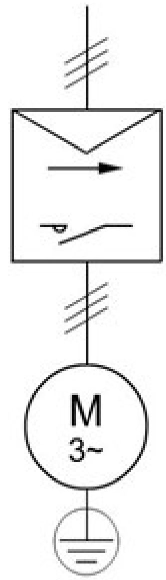


Figure IV.2: Developed diagram of a three-phase motor **Figure IV.3:** Block diagram of a three-phase motor

P1: power-on indicator light.P2: Indicates start- up. P3: Indicates overload fault.

The logic equation of the KM1 pre-actuator is written as follows:

$$\mathbf{KM1 = \overline{F1}\ S2\ (S1 + KM1)}$$

- **Operating diagram**

Diagrams or explanatory tables make it easier to understand the diagrams and provide additional information. We distinguish between:

The sequence diagram or table, which facilitates the analysis of successive actions in a given order, The time sequence diagram or table, which takes in to account the value of the time intervals between successive actions.

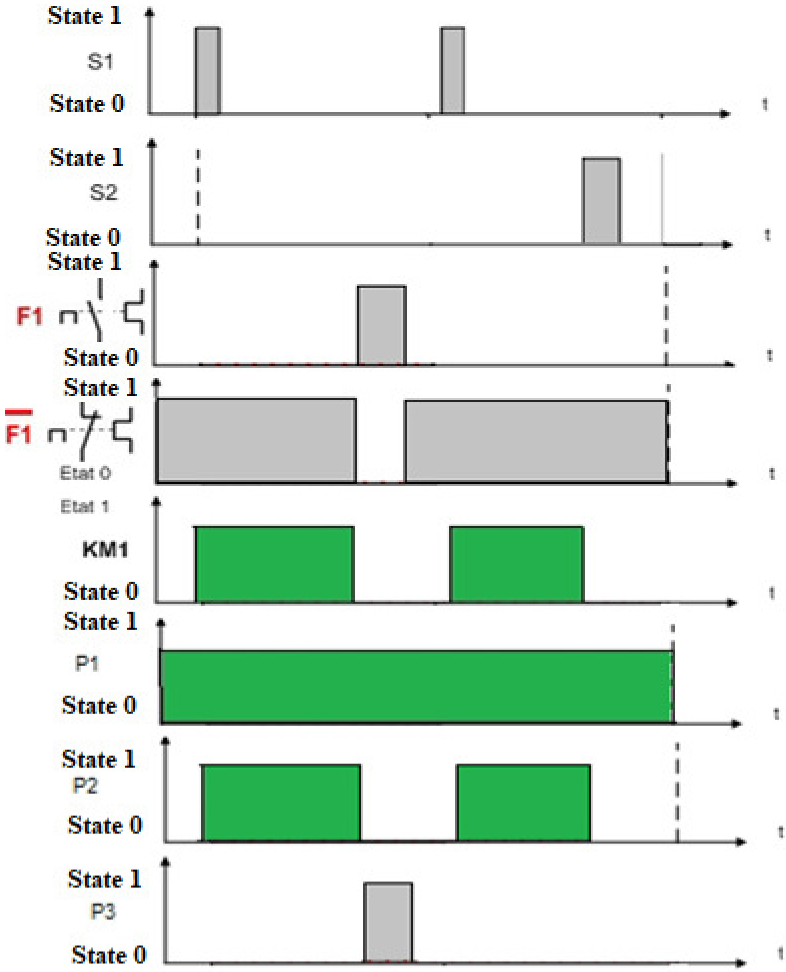


Figure IV.4: Operating diagram of a direct-start assembly for an induction motor.

- **Current draw**

Over current at start-up may be 4 & 8 times rated current , Id = 4 to 8 In

- **Motor torque**

On start-up, motor torque averages 1.5 to 2 times rated torque.

Table IV.1: Advantages and disadvantages of Direct-on-Line (DOL) Starting

Benefits	Disadvantages
⇨ Simplicity of equipment. ⇨ High torque. ⇨ Short start-up time.	⇨ High current draw ⇨ Rough start

2. Forward - Reverse Direct ON Line (DOL) starting

1. Reminders

To change the direction of rotation of a three-phase asynchronous motor, two of the three phases of the supply circuit must be reversed, as shown in Figure IV**. 5**

Determining the coupling Based on the information given on the motor nameplate and the mains supply, the user must couple the stator windings in the correct delta or star configuration.

- If the lowest voltage on the motor nameplate corresponds to the voltage between phases of the network, we adopt **the Δ coupling.**
- If the highest voltage on the motor nameplate corresponds to the voltage between mains phases, **Y-coupling is** adopted.

Winding coupling on the terminal board Terminal strips are used to ensure the selected coupling of the windings on the motor terminal board.

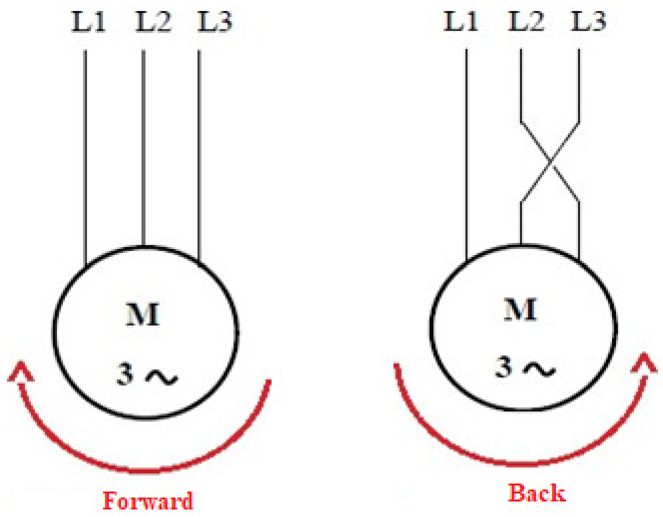
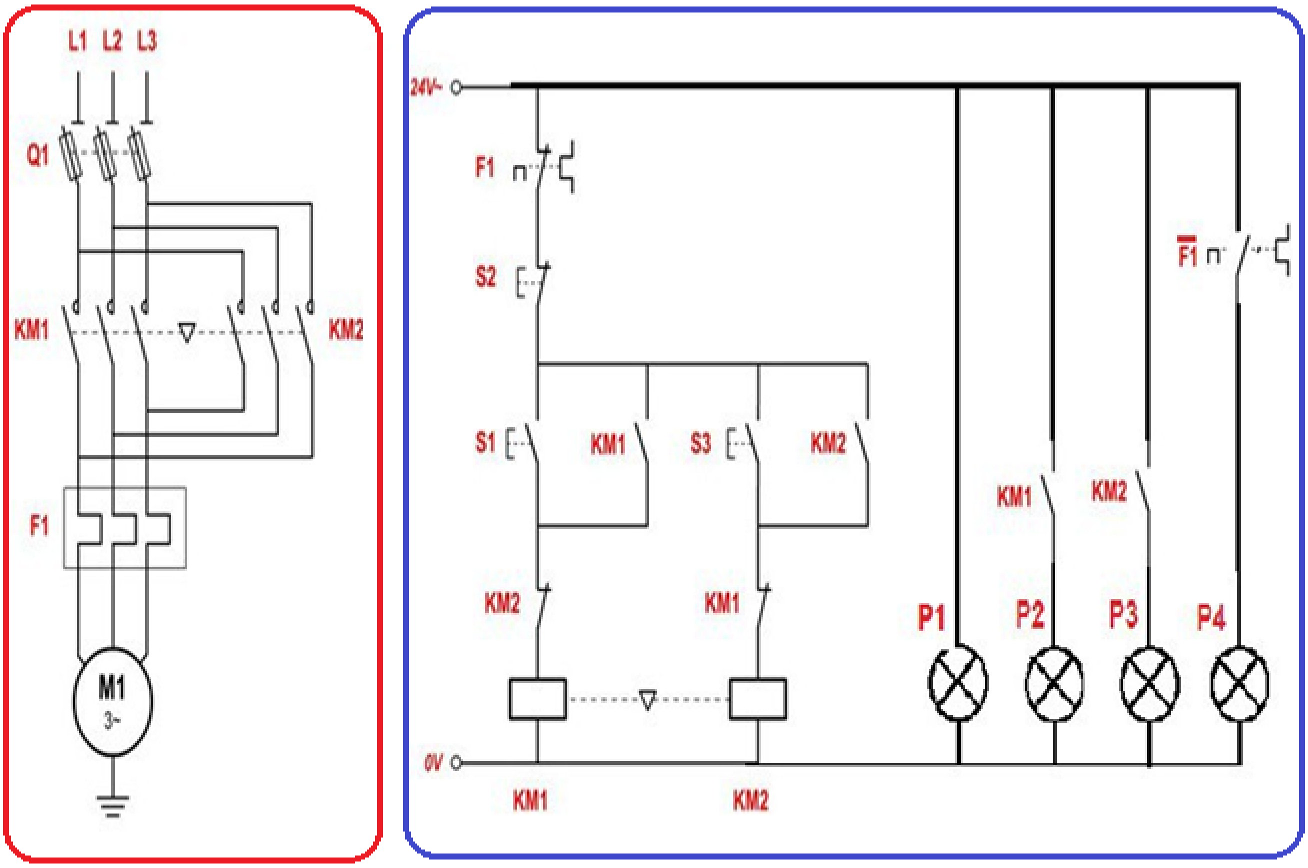


Figure IV.5: Principle of reversing the direction of rotation of an induction motor

Consider the following control and power diagram for a three-phase motor:



Power circuit Control circuit

Figure IV.6: Developed diagram of a three-phase motor with two directions of rotation

P1: Power-on indicator lamp.

P2: indicator lamp for forward start.

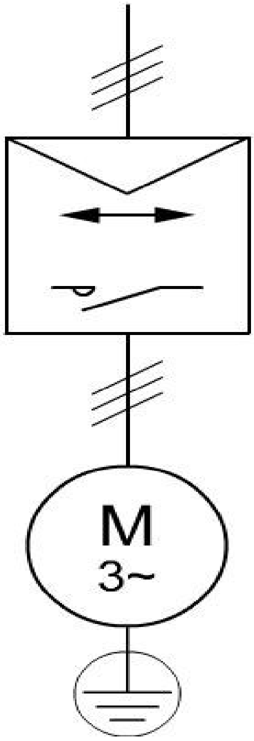
P3: indicator lamp for back start.

P4: indicator lamp for overload fault.

The logic equation for the KM1 and KM2 pre-actuators can be written as follows:

KM1= ($\overline{F1}$) S2 (S1+KM1) $\overline{KM2}$ KM2= ($\overline{F1}$) S2 (S3+KM2) $\overline{KM1}$

The two-way rotation block diagram for an asynchronous motor and the operating diagram are illustrated in the following figures:



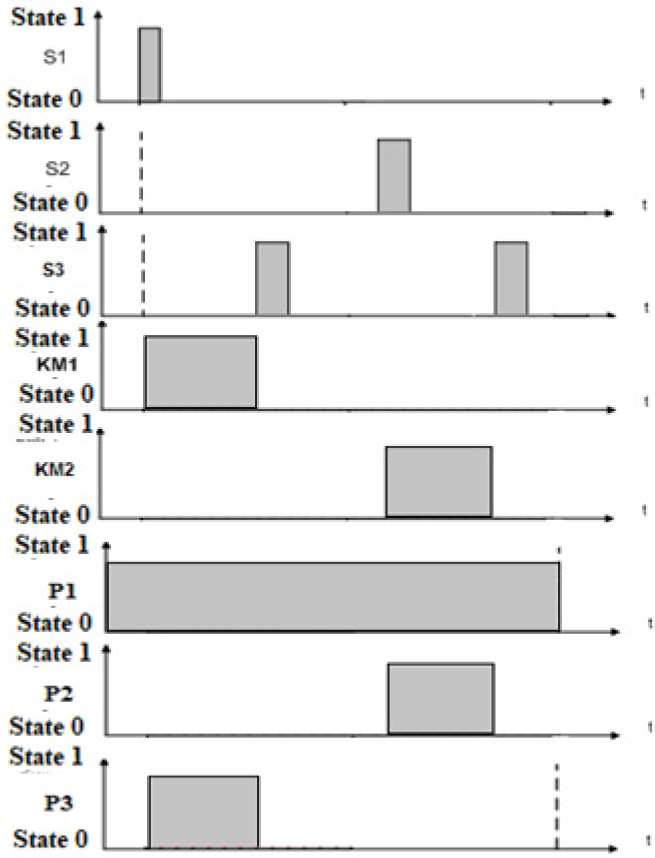


Figure IV.7: Functional diagram

Figure IV.8: Operating diagram

3. **Star-delta start**

   1. **Starting current limiting principle**

In contrast to direct on line (DOL) starting, the starting of medium and high-power motors requires the use of starting current limiting procedures, while maintaining the mechanical performance of the motor/driven machine assembly.

There are two technical types of action:

- **Actiononthestator**,whichconsistsinreducingthevoltageacrossthestatorwindings:
  - Star-delta coupling,
  - Elimination of stator resistances,
  - Use of an auto-transformer.

  This type of action is used for medium-power motors.

- **Action on the rotor:** Increases rotor resistance on start-up:
  - Elimination of rotor resistance,
  - Use of multi-cage motors...

In addition to reducing starting current, this starting method also increases starting torque. This type of starting is used for high-power motors.

2. **Star-delta starting**

The engine starts in two stages:

- **1st step**: each stator winding is supplied with a reduced voltage U/√3 usingY coupling.

  t1 is the time required for the motor speed to reach approximately 80% of its rated speed.

- **2nd step**:each stator winding is supplied with its rated voltage changing the coupling to delta.

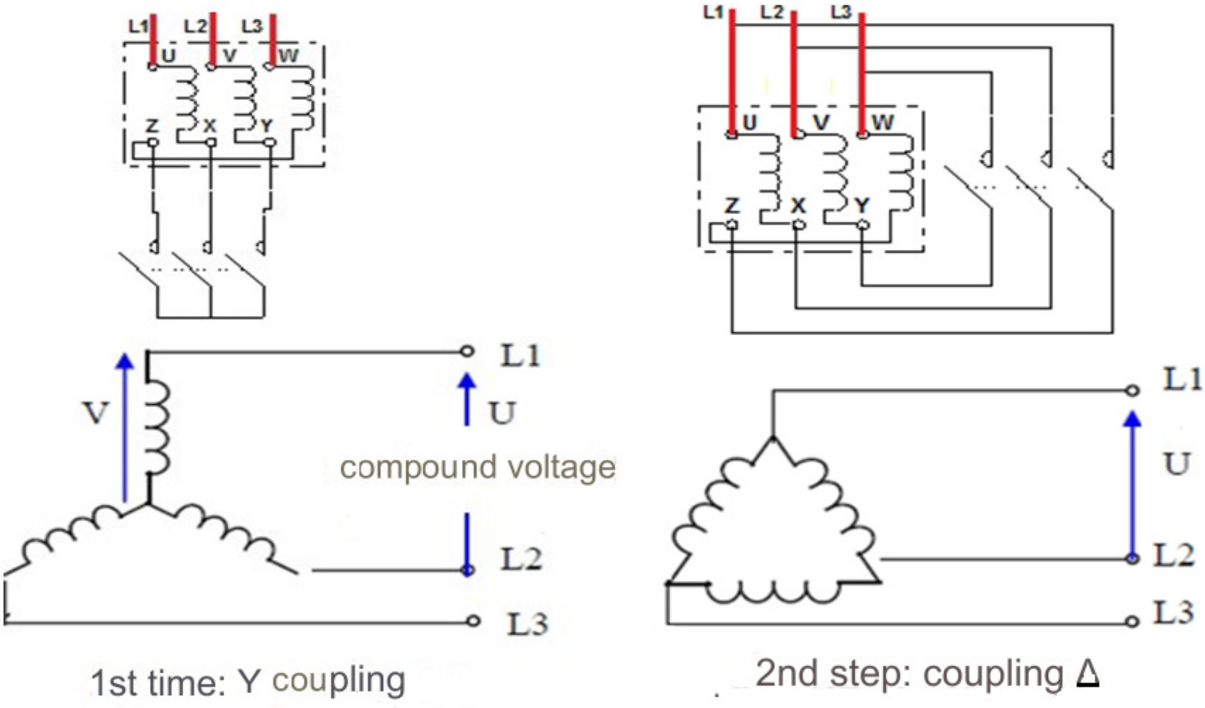


Figure IV.9: Y-Δ coupling principle

This type of starting is used for Δ-coupled motors during normal operation.

Example: A 400V/690V motor on a 230V/400V network or 230V/400V motor on a 133V/230V network

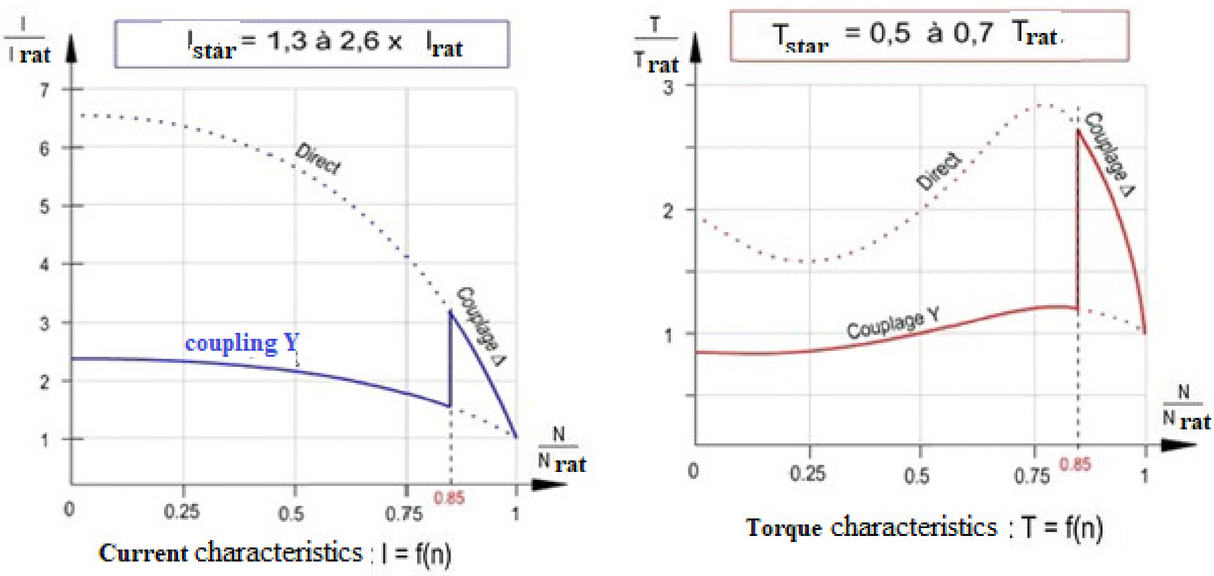


Figure IV.10: Torque-current characteristics as a function of speed for starting Y-Δ

Torque and current at start-up are reduced by around 3 times compared with direct starting. Due to the significant decrease in starting torque the engine cannot start under load

3. Time delay

To achieve automated switching from Y to Δ coupling, we use a timed contact that makes or breaks a contact after certain preset times to enable our equipment to operate properly.

The timed contact enables a contact to be made or opened a certain time after the contact or which actuates it has closed (when working) or opened (when idle).

Off delay relay 0.1-30s

On delay relay 0.1-30s

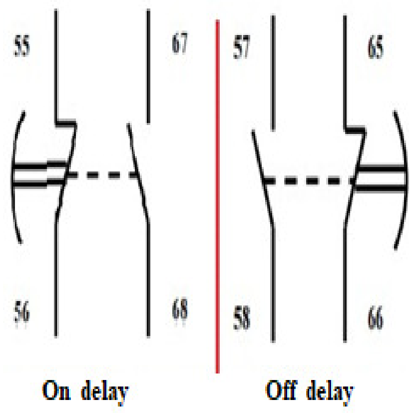


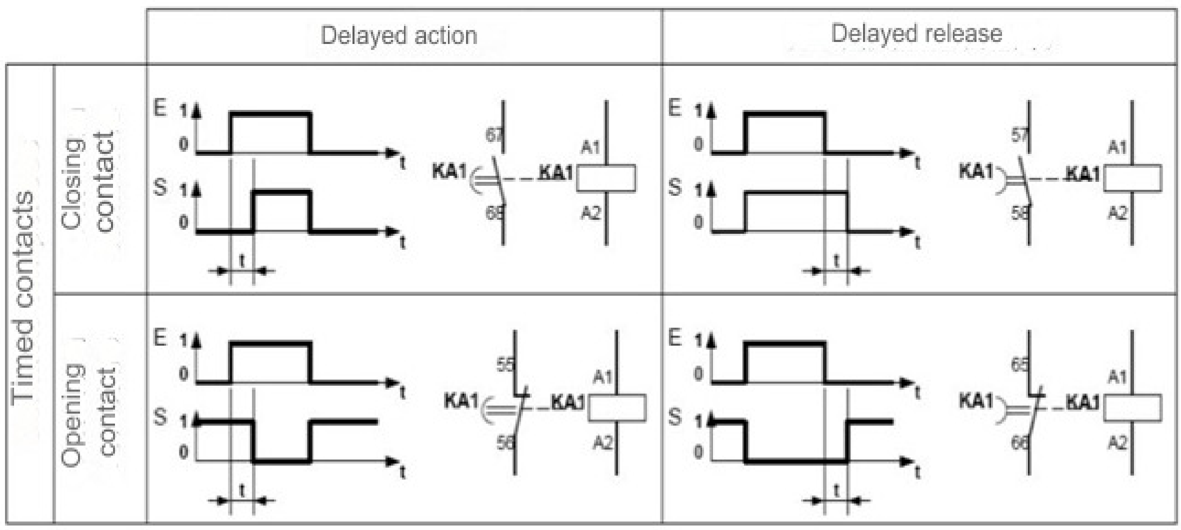
Figure IV.11: Timing principle for Y-Δ start-up

There are two types of timer relays:

- Time-delay relay
- Time-delayed release relay

The operating principle is illustrated in the following table:

Table IV.2: Time-delayed actions



Consider the following control and power diagram for a three-phase motor:

1st step: We must power the motor using KM2 while coupling it in star using KM1.

2nd step: We maintain the power supply of the motor through KM2, KM1 is replaced by KM3 which ensures the coupling of the motor in delta. Each winding must then be between two different phases.

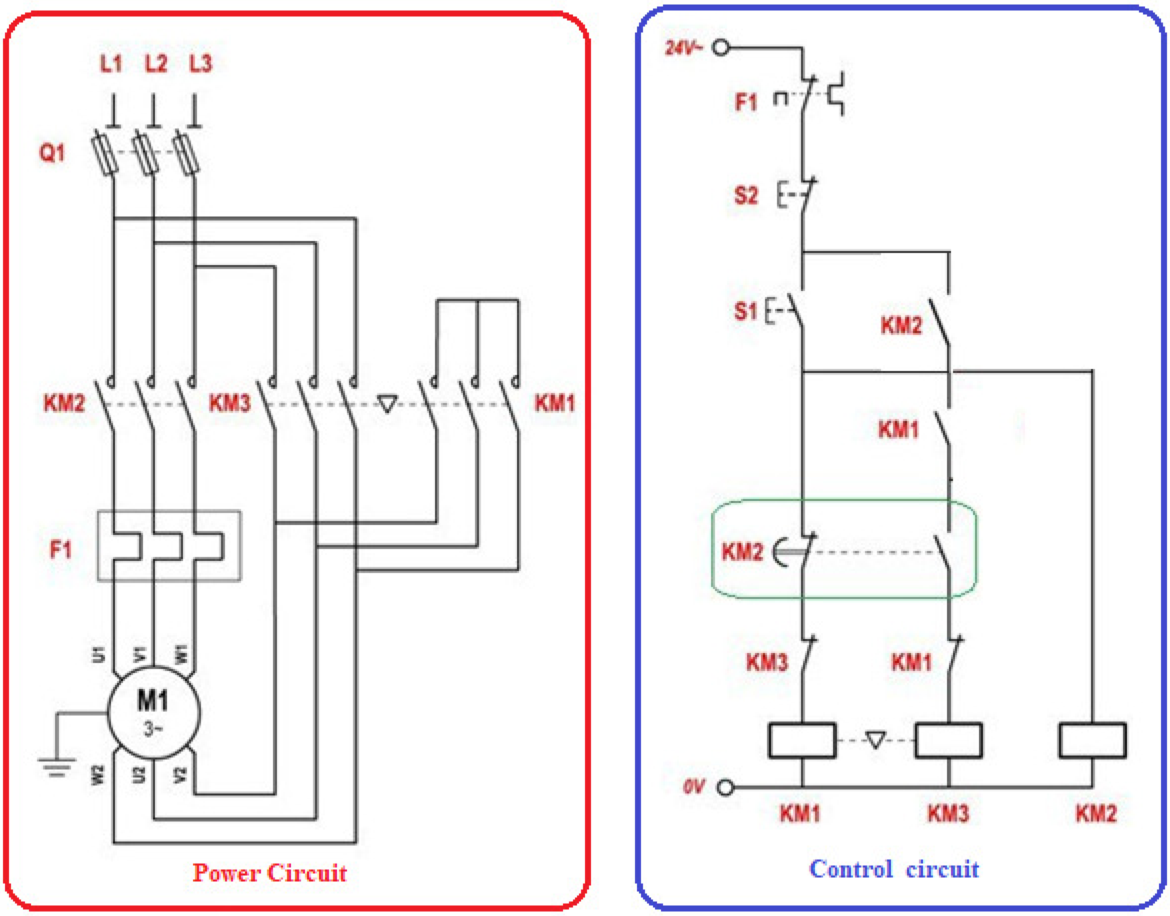


Figure IV.12: The developed diagram of a three-phase motor starting Y-Δ

The block diagram of the Y-Δ start-up of an induction motor and the operating diagram are shown in the following figure:

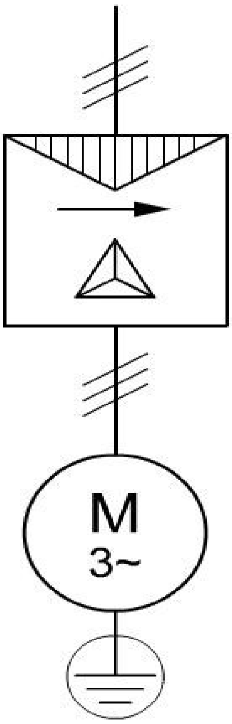


Figure IV.13: Block diagram

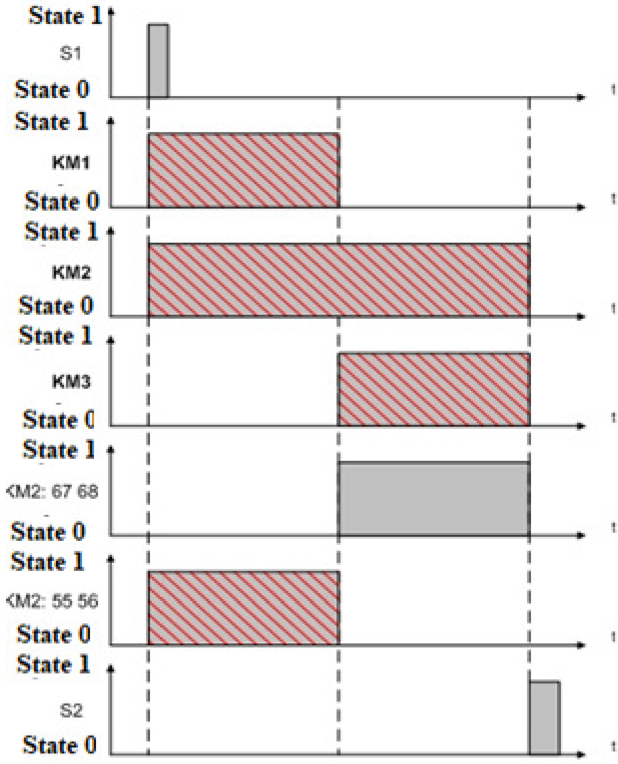


Figure IV.14: Operating diagram

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