



UNIVERSITAT
POLITÈCNICA
DE VALÈNCIA

The Contactor

Surnames, name	Antonino Daviu, Jose Alfonso (joanda@die.upv.es)
Department	Departamento de Ingeniería Eléctrica
Centre	Universitat Politècnica de València



1 Summary

The aim of this paper is to present a basic introduction to the operation of the Contactor. This is a switching element often employed in electrical industrial installations for automation purposes. The paper intends to explain, in a very simple manner, the following aspects related to the Contactor:

- Definition and main characteristics.
- Constituting elements and operation principles.
- Basic specifications.
- Types of Contactors.
- Applications.

This work is devoted to students or professionals that are involved in electrical installations design and, more specifically, in the basic switchgear used in those installations.

2 Introduction

A Contactor is a mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including overload conditions (it cannot break short-circuit currents) [4].

The primary function of the contactor is a *switching function* (connect and disconnect parts of the installation).

The two main characteristics of the contactor are:

- *High switching frequency*: it can make/break the circuit a high number of times per hour (10 to 10^3 cycles per hour, with 10^5 to 10^7 cycles per life).
- *Electrical remote actuation*: it is not operated manually but electrically, by feeding its coil.

These two characteristics make its use ideal for the *automation of industrial applications*.

Contactors can be also combined with overload relays to create motor starters.

Specific information on L.V. Contactors can be found in the norms UNE 20-109 (EN 60-947-2) and IEC 60947.

3 Objectives

The following learning objectives are pursued in this paper:

- To understand the basic elements of a contactor.
- To be able to list and describe the basic terms defining a contactor and enabling its specification.
- To be able to describe and compare the different types of contactors.
- To understand specific applications of the contactors.

4 Development

4.1 Basic parts and operation principle

A Contactor has three main parts or circuits:

- **Control circuit:** The control circuit enables to feed the coil of the contactor. When the coil is supplied with a voltage, the fixed part of the contactor (yoke) is magnetized and it attracts the moving part (core). This movement causes the closing of the main contacts of the contactor and, hence, the establishment of current in the main circuit. When the coil is not fed, the main contacts open and, consequently, the current in the main circuit is interrupted.
- **Main circuit:** is the circuit that the contactor opens/closes by means of its main contacts. In Figure 1, it would be a three-phase circuit.
- **Auxiliary circuit:** It is based on all the conductive parts of a contactor (auxiliary contacts) designed to be inserted in a different circuit from the main circuit and the contactor control circuits. The state of the auxiliary contacts is linked with the state of the main contacts of the contactor; there are two main types of auxiliary contacts:

1) The *Normally Opened contacts (NO)* that behave as the main contacts of the contactor (i.e. if the main contacts open, they open and vice-versa).

2) The *Normally Closed contacts (NC)* that behave inversely (i.e. if the main contacts open, they close and vice-versa).

The marking system is according to the EN 60947- 4 -1 and EN 50011. On the upper (generally the feed) side the marks of the main contacts are: 1 L1; 3 L2; 5 L3 and on the lower (loading) side: 2 T1; 4 T2; 6 T3 (see Figure 3).

The figures of the auxiliary contacts are always two digit numbers. The first number refers to the position of the auxiliary contact-block, the second number refers to the function mode (made or break contact) [5].

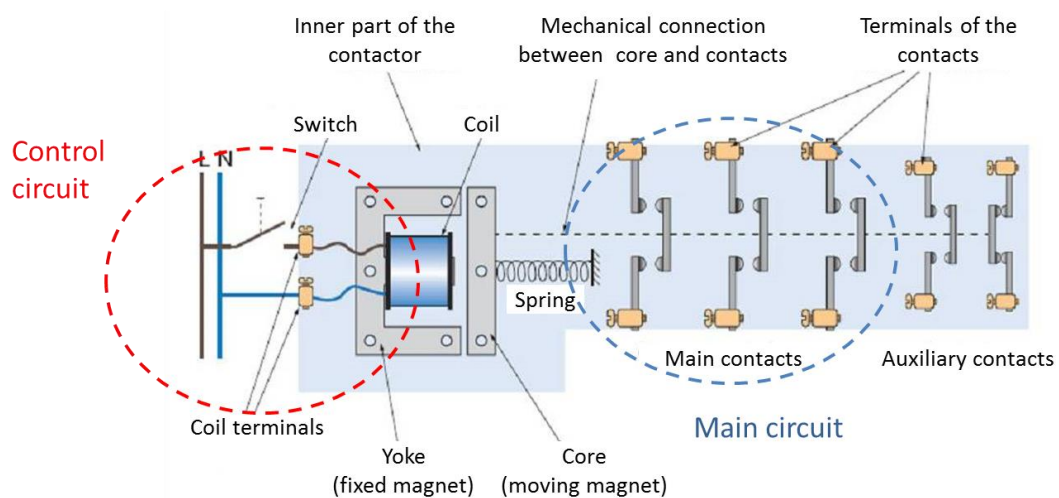


Figure 1. Main elements of a contactor (Source: [6])

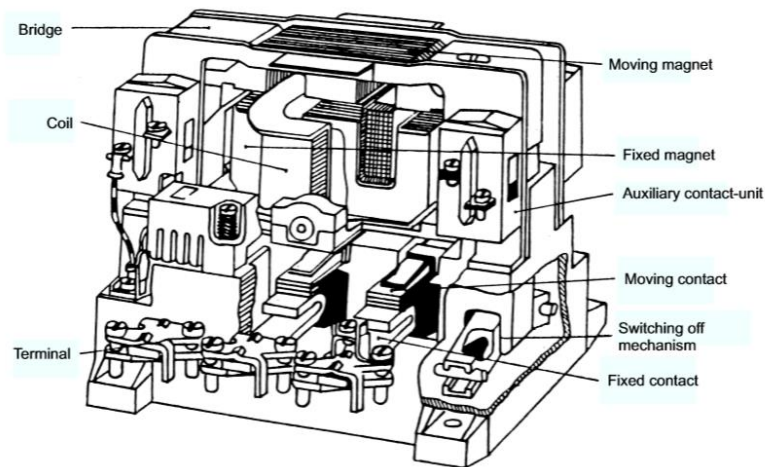


Figure 2. Constructive elements of a contactor (Source: [5])

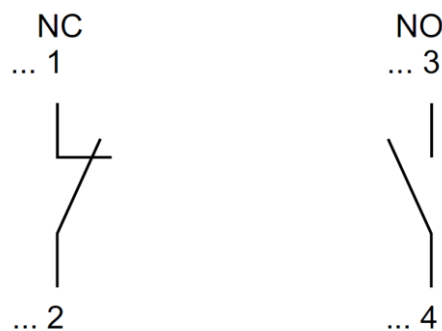


Figure 3. Representation and denomination of auxiliary contacts (Source: [5])

4.2 Basic specifications

Some basic characteristics defining a Contactor are explained next [4]:

- **Rated Operational Current (I_e):** Current rated by the manufacturer. It is mainly based on the rated operational voltage U_e , the rated frequency, the utilization category, the rated duty and the type of protective enclosure, if necessary.
- **Conventional Free Air Thermal Current (I_{th}):** Current that the contactor can withstand in free air for a duty time of 8 hours without the temperature rise of its various parts exceeding the maximum values given by the standard.
- **Operating Cycle or Cycle:** Includes one making operation and one breaking operation.
- **Cycle Time:** This is the sum of the current flow time and the no-current time for given cycle.
- **Electrical Durability:** Number of on-load operating cycles that the contactor is able to carry out. It depends on the utilization category.



- **Mechanical Durability:** Number of no-current operating cycles that a contactor is able to carry out.
- **Assessed Failure Rate:** Defined according to IEC 60947-5-4. This rate is given in standard industrial environments for the contactor relays and for the built-in auxiliary contact of contactors.
- **Load Factor:** Ratio of the on-load operating time to the total cycle time x 100.
- **Switching Frequency:** Number of switching cycles per hour.
- **Coil Operating Limits:** Expressed in multiples of the nominal control circuit voltage U_c for the upper and lower limits.
- **Mounting Position:** Comply with the manufacturer's instructions. Restrictions are to be taken into account for certain mounting positions.
- **Rated Breaking or Making Capacity:** Root mean square (r.m.s.) value of the current that the contactor is able to break or make at a given voltage according to the conditions specified by standards and for a given utilization category.
- **Intermittent Duty:** Duty during which the contactor is successively closed or open for periods which are too short to enable the contactor to achieve thermal balance.
- **Ambient Temperature:** Air temperature close to the contactor.
- **Time**
 - **Time constant:** Ratio of the inductance to the resistance ($L/R = \text{mH}/\Omega = \text{ms}$).
 - **Short-time withstand current:** Current that the contactor is able to withstand in closed position for a short time interval and in specified conditions.
 - **Closing time:** Time interval between the beginning of the closing operation and the instant the contacts touch on all the poles.
 - **Opening time:** Time interval between the specified starting instant of the opening operation and the instant the contacts separate on all the poles.
- **Rated Control Voltage (U_c):** Control voltage value for which the control circuit is sized.
- **Rated Operational Voltage (U_e):** Voltage to which the contactor's utilization characteristics refer. In three-phase it is the phase-to-phase voltage.
- **Rated Insulation Voltage (U_i):** Reference voltage for dielectric tests and creepage distances.
- **Rated Impulse Withstand Voltage (U_{imp}):** Peak value of an impulse voltage, having a specified form and polarity, which does not cause breakdown in specific test conditions.
- **Shock Withstand:** Requirement for vehicles, crane drives, installations on board ships and plug-in equipment. For the acceptable "g" values, the contacts must not change position and the thermal overload relays must not trip.
- **Resistance to Vibrations:** Requirements for vehicles, boats and other means of transport. For the specified vibration amplitude and frequency values the device must remain able to operate.

- **Utilization category:** Set of normalized utilization conditions that correspond to real applications and that determine the conditions in which the breaking takes place and that facilitates the selection of the contactors. Figure 4 shows the utilization categories for contactors according to the IEC 60947.

Utilization Categories for Contactors According to IEC 60947-4-1:		
Alternating current:	AC-1	Non-inductive or slightly inductive loads, resistance furnaces.
	AC-2	Slip-ring motors: starting, switching off.
	AC-3	Cage motors: starting, switching off running motors.
	AC-4	Cage motors: starting, plugging, inching.
	AC-5a	Discharge lamp switching.
	AC-5b	Incandescent lamp switching.
	AC-6a	Transformer switching.
	AC-6b	Capacitor bank switching.
	AC-8a	Hermetic refrigeration compressor motor control with manual resetting of overload releases.
	AC-8b	Hermetic refrigeration compressor motor control with automatic resetting of overload releases.
Direct current:	DC-1	Non inductive or slightly inductive loads, resistance furnaces.
	DC-3	Shunt motors: starting, plugging, inching, dynamic breaking of d.c. motors.
	DC-5	Series motors: starting, plugging, inching, dynamic breaking of d.c. motors.
	DC-6	Incandescent lamp switching.

Utilization Categories for Contactor Relays According to IEC 60947-5-1:		
Alternating current:	AC-12	Control of resistive loads and static loads with opto-coupler isolation.
	AC-13	Control of static loads with transformer isolation.
	AC-14	Control of weak electromagnetic loads (≤ 72 VA).
	AC-15	Control of electromagnetic loads (> 72 VA).
Direct current:	DC-12	Control of resistive loads and static loads with opto-coupler isolation.
	DC-13	Control of d.c. electromagnets.
	DC-14	Control of d.c. electromagnets having economy resistors.

Figure 4. Utilization categories for contactors according to the IEC 60947

4.3 Characteristic curves

4.3.1 Service life curves

These curves provide the contactor life expectancy based on utilization category and rated voltage.

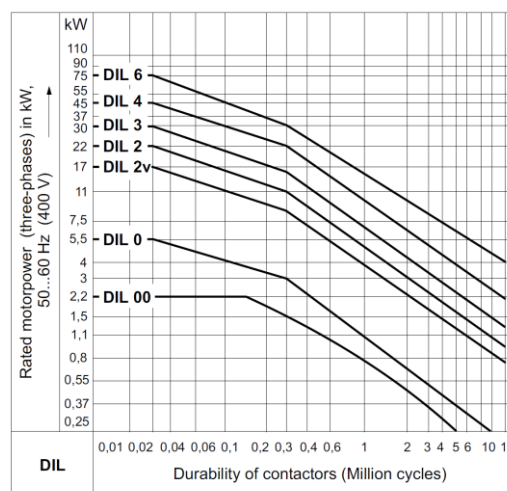


Figure 2. Service life curve for different contactors (AC-4) (Source: [5])



4.4 Types of Contactors

There are different classifications of the industrial contactors [7]. One of the main classifications for contactors is depending on their geographic context: in Europe and Asia stands the **International Electrotechnical Commission (IEC)** classification while in North America, the **National Electrical Manufacturers' Association (NEMA)** is employed. In the case of North America area, electrical contactor manufacturers have classified the contactors into three main groups: NEMA rated contactors, Definite purpose contactors and General purpose contactors.

The differences between the IEC and NEMA classified components is reflective of their size, speed, functionality and power. IEC and NEMA also rate their components based on different philosophies. North American (NEMA) general purpose machine tool contactors generally emphasizing simplicity of application while definite purpose and European rating (IEC) philosophy emphasizes design for the intended life cycle of the application. Over all, contactors are split between these two classifications. Some examples include:

- AC Mechanically Interlocked - IEC
- DC Mechanically Interlocked - IEC
- AC Reversing - IEC
- AC Non-Reversing - IEC
- AC Reversing - NEMA
- AC Non-Reversing – NEMA

Note that, in the previous typology, a *non-reversing contactor* is just a single contactor, with three main switching terminals (1 per phase for a 3-phase supply to the motor.) A *reversing contactor* is an assembly of two of the above, with a mechanical and electrical interlock between them, so only one contactor can be closed (giving power supply to the motor) at any time. The Forward/Reverse - Up/Down - Left-right etc. are usually opposite motions, and the opposite motions are obtained via labelled switching buttons which energizes the coil of the correct contactor, mechanically locking the other motion contactor and also electrically preventing it from closing.

Another popular type of contactor is a **Definite Purpose Contactor**. Definite Purpose Contactors are electrically operated switching devices specifically designed for the heating, ventilation, air conditioning and refrigeration (HVAC) industry. They are controlled by automatic thermostat control or manual pushbutton interfaces.

In the case of **IEC contactors**, they can be sub-classified according to several additional possible criteria, among them:

- **Actuation:** according to the actuation mechanism they can be classified as pneumatic, electromagnetic, electromechanical or hydraulic.
- **Contacts disposition:** according to the atmosphere in which the circuit break takes place can be classified in: air, oil, SF₆ or vacuum contactors.
- **Type of current:** according to the current of the main circuit: AC or DC contactors.
- **Rated Voltage:** according to the voltage of the main circuit: Low Voltage (<1000V) or High Voltage contactors (>1000 V).



- **Breaking capacity:** according to their breaking capacity the contactors can be classified in Power (certain breaking capacity) or Auxiliary (low or null breaking capacity).

4.5 Applications

Among the possible applications of the contactors, we can remark [7]: lighting circuits, heaters and transformers. Contactors are often used to provide central control of large lighting installations, such as an office building or retail building. To reduce power consumption in the contactor coils, latching contactors are used, which have two operating coils: one coil, momentarily energized, closes the power circuit contacts, which are then mechanically held closed, whereas the second coil opens the contacts.

Magnetic starters include a contactor as an essential component, while also providing power-cutoff, under-voltage, and overload protection. Electromagnetic contactors are actuated by electromechanical means. They make and break power circuits supplying loads as electric furnaces, lights, transformers, capacitors, heaters and, when overload relays or inherent protectors are used, motors. Pushbuttons and selector switches, like the ones on a control panel, are used in hundreds of manufacturing industries. Each button and switch is connected to a contactor for use in making or breaking an electrical circuit remotely. They are used in applications such as elevators, pools, food processing, pumps/compressors, lighting, hoists and cranes, battery chargers, printing presses, vending machines, and agricultural processes [7].

5 Conclusions

This work constitutes a basic introduction to one of the most common elements in Low Voltage electric switchgear: the contactor. The work explains the basic parts of a contactor and its operation principles. Moreover, the basic quantities used for the specification of a contactor are enumerated and explained. The work describes the main characteristic curve. The contactor typology is also analyzed in the paper and, finally, its main applications are described.

6 References

6.1 Textbooks:

- [1] Roger, J.; Riera, M.; Roldán, C.: "Tecnología Eléctrica", Ed. Síntesis, 2010, Cap. 8.
- [2] Roger, J.; Riera, M.; Roldán, C.; Antonino, J.A.: "Exercises and questions". Editorial UPV. 2010.
- [3] Reglamento Electrotécnico de B.T. (R.B.T.2002) (MIE-BT).



UNIVERSITAT
POLITÈCNICA
DE VALÈNCIA

6.2 Technical catalogs:

[4] ABB technical catalog, low voltage products, Section 7, 'Certification and approvals. Coordination with short-circuit protection devices'.

[5] GANZ KK. DIL Universal Contactors. Technical catalog, 2001.

6.3 Websites:

[6] Automatismoindustrial. Curso: Montaje y Mantenimiento de Instalaciones eléctricas de baja tensión. <http://automatismoindustrial.com/contactores/>

[7] GALCO, Contactors. <http://www.galco.com/comp/prod/cont.htm>.