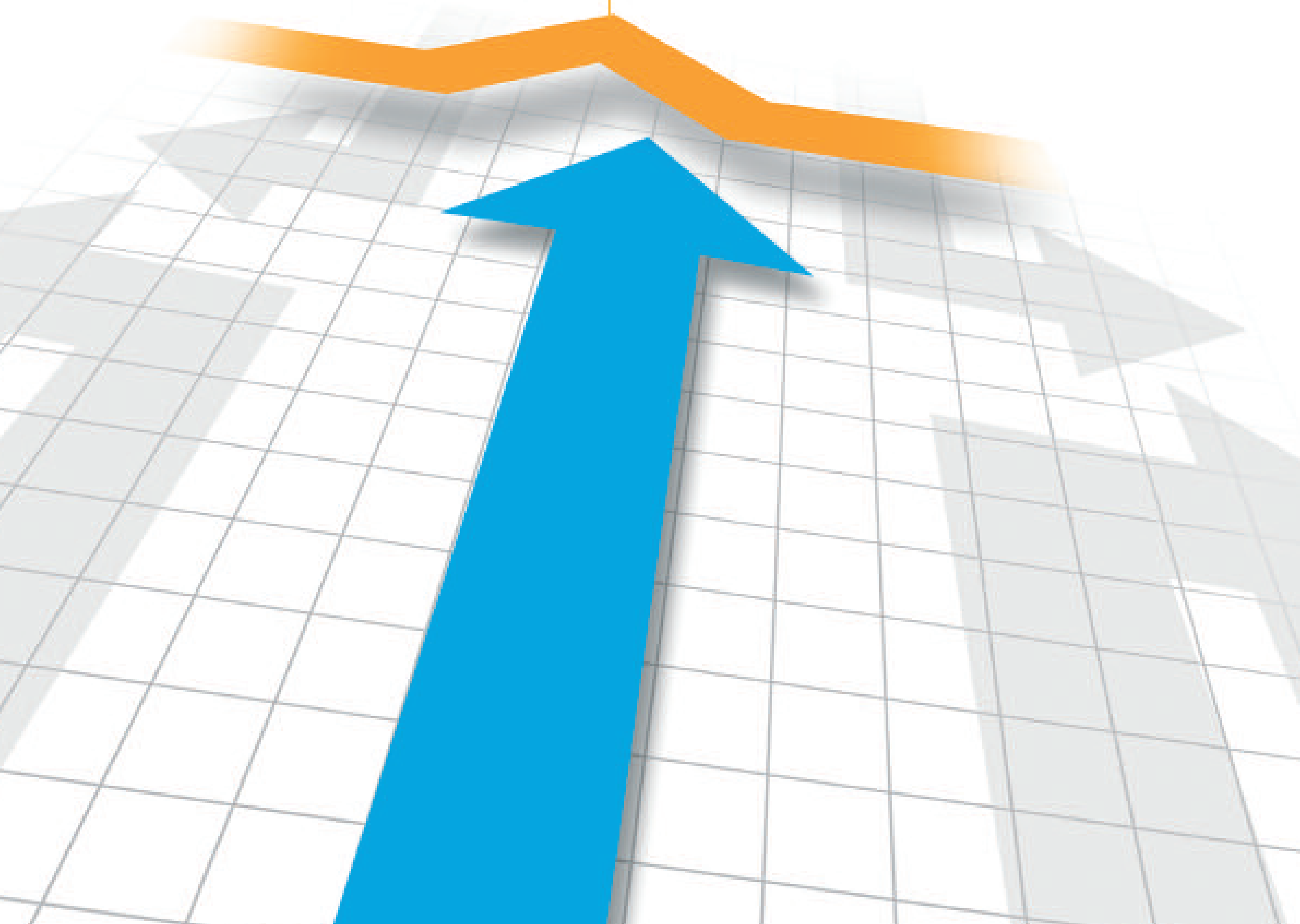
11 chapter
Equipment manufacturing

Presentation:
- *Step by step manufacturing*
- *Quality rules*
- *Relevant standards*



Summary

11. Equipment manufacturing

Automated systems use equipment that implements products to facilitate the installation, wiring and connection of automation components. These products have to comply with local and international standards as well as safety standards for the protection of people and property.

Equipment is built in 3 stages:

- *design (diagram, program writing, choice of material, installation study);*
- *construction (assembly, wiring, tests, housing);*
- *installation (wiring, connections, commissioning).*

To complete these three stages satisfactorily, thought must previously be given to:

- *the understanding of potential problems which could have an impact on the safety and/or availability of the equipment;*
- *implementation of preventive actions and/or alterations to the initial automation diagram;*
- *the capacity of any subcontractors to comply with the requirements;*
- *the compliance of the equipment with the requirements.*

The purpose of this section is to describe the rules for implementing automation system components and the Schneider Electric products which can be used to build them.

A methodology and good engineering practice based on experience for each of the three stages make it possible to build reliable and cost-effective equipment.

11.1 Equipment design

Successful construction of automation system equipment basically depends on the understanding of exact specifications.

The design tools, diagram drawings, choice of components and their installation can differ according to the complexity of the system and the choices made by the service provider. Besides this, while a simple standalone machine may be adequately equipped by a mechanic and an electrician or automation system engineer, equipping more complex machines for production cells or process runs often requires the work of multidisciplinary teams. This implies project management and is beyond the scope of this publication.

Specifications

Specifications for the control section must include all the requisite elements for the project. They are closely tied to the specifications for the operating section (mechanics and actuators). The information they contain is used to:

- choose the solution to implement;
- build the equipment itself;
- run operating tests;
- define costs and schedules;
- refer to for acceptance.

To clarify customer requirements, it is preferable to structure the specifications as follows:

- general aspects: overview of the application, standards and recommendations, any material constraints;
- characteristics of the power supply, etc.;
- use: layout of control devices, operating modes, frequency of use, etc.;
- functional features: functions to perform, possible extensions, man-machine dialogue, peripheral devices, etc.;
- environment: temperature, hygrometry, vibrations, shocks, corrosive atmosphere, dust, etc.;
- special software: diagnosis help programs, supervision, communication protocols, etc.;
- adjustment: type, procedures, identification;
- on-site acceptance test procedures;
- accompanying documents;
- any other information which could affect the equipment-building process, such as packaging for transport.

11.2 Choice of supplier

To build equipment, the order initiator is advised to select a panel builder with ISO9000 certification.

Using a certified supplier will simplify discussions, cut down on checks, ensure an up-to-date equipment file and problem-free commissioning and facilitate maintenance. This helps to control costs.

ISO9000 standard

Equipment is increasingly sophisticated, technologies ever more critical and statutory requirements more and more severe.

All this can make it much harder to control events by reason of their complexity.

The order initiator must be certain that when the equipment is built, it will correspond exactly to the specifications and that all the requisite precautions have been taken.

In particular, the inevitable changes occurring during the manufacturing must be perfectly understood and applied by the panel builder, the staff involved in the process must be properly trained and non-compliant products must be identified and set aside.

This implies the development of an ongoing “Customer-Supplier” relationship.

The supplier must provide the customer with proof of competency and skill regarding the quality of the offer and control of the production process.

The customer must be assured of the supplier’s capacity to perform these undertakings which only stringent organisation can ensure.

The ISO9000 standard and certifications are designed to facilitate this customer-supplier relationship by quality management.

Quality management

“Quality management” means what an organisation does to ensure that the product, in this instance the equipment built to the customer’s specifications, complies with requirements when it leaves the supplier’s workshops.

The way an organisation manages its processes cannot fail to affect the final product. The ISO 9000 series focuses on knowing whether everything has been done to ensure a product meets customer requirements.

The international ISO9000 standard is a generic one covering ISO 9001, 9002 and 9003.

The difference between ISO 9001, ISO 9002 and ISO 9003 is confined to the field of application:
- ISO 9001 sets requirements for organisations with a business ranging from design and development to production, installation and related services;
- ISO 9002 is the standard for organisations that do not design or develop. It sets the standards for production, installation and related services;
- ISO 9003 is the standard for organisations that basically use inspections and tests to ensure that end services meet specified requirements.

The order initiator will choose the panel builder whose organisation best matches the services required. An ISO 9002 certification is usually the requisite minimum.

The choice of the order initiator will be made after examining the Quality Manual of the supplier(s) involved. This describes the organisation and management system adopted by the company.

11.3 Drafting diagrams and programs

Control and power diagrams

Control and power diagrams are usually drawn using graphics software linked to a database where graphic symbols and standard diagrams are stored.

The diagrams can be:
- created from scratch from database content;
- or adapted from an existing similar diagram.

PLC programs can also be developed with programming software and software workshops.

Complex equipment usually relies on one or more programmable multifunction PLC's.

Stop/start modes

The stop/start modes of an automation system are analysed by the AIADA and classified in a graphic guide called GDOSM which is used, regardless of the control technology, to define the operating modes or statuses of the system based on a specific vocabulary, possible links between the modes or statuses and upgrading conditions.

Operating procedures: functional analysis

The operating modes required for production are:
- normal production mode,
- preparation or closing modes;
- inspection modes, etc.;
- stopping procedures;
- input / output data files;
- identification of operations in order to structure the PLC's programs *(⇨ Fig. 4)*.

Failure procedures

These cover the operation of the machine in the event of a problem:
- emergency stop;
- degraded operation, etc.

Operating safety

Standard requirements

The operating safety of an automated system is its capacity to operate:
- without danger to people and property (safety);
- without hindering production when a failure occurs (availability).

Safety should be viewed as an aspect of risk analysis, legislation and relevant standards. It is examined through a risk evaluation procedure applied successively to the product, the process (operation and control) and utilisation. For further information on this topic, please refer to "Machine safety Parts 1 and 2" distributed by *Schneider Training Institute*.

European legislation is based on the machine directive (89/392/EEC) defining basic requirements in design and construction of industrial machines and installation for free circulation of these goods in the European Community.

□ Analysis tools

Analysis tools such as FMECA (Failure Modes, Effects and Criticality Analysis) can provide a systematic approach to all aspects of failure and provide suitable solutions.

FMECA is designed for evaluating the impact or criticality of failure modes in system components on the reliability, sustainability, availability and safety of the system.

The FMECA method lists the failure modes of components and sub-units and evaluates the effects on all the functions in a system.

It is widely recommended throughout the world and consistently used in all hazardous industries (nuclear power, space, chemical, etc.) for making preventive analyses of operating safety.

Before an FMECA analysis can be run, the system and its environment must be accurately understood. This information is usually obtained in the results of the functional analysis, risk analysis and any feedback.

Next, the effects of the failure modes must be evaluated. To find the effects on a specific entity, the components directly interfaced with it are examined first (local effect), and then gradually out to the system and its environment (global effect).

It is important to note that when a specific entity is examined for a specific failure mode, all other entities are assumed to be in their rated operating condition.

FMECA is based on the well-established fact of non-simultaneous failures.

The third step is to classify the failure mode effects by their level of criticality in relation to certain operating safety criteria predefined for the system according to the requisite objectives (reliability, safety, etc.).

The failure modes of a component or sub-unit are grouped by the criticality level of their effects and prioritised accordingly.

This typology helps to identify the most critical elements and propose the "strictly necessary" actions and procedures to remedy them. This process of results interpretation and recommendation implementation is the final step in FMECA.

To keep FMECA to the strictly necessary and control the number of entities to examine, it is advisable to run functional FMECA analyses. This helps to detect the most critical functions and thus confine the "physical" FMECA to the components that perform all or part of the functions.

FMECA methodology ensures:

- a different view of the system;
- means of thought, decision and improvement;
- information to use in operating safety examinations and remedial action.

11.4 Programming methodology

Programming organization

Industry uses more and more software programs for its production purposes. There is such a wide variety of these applications that understanding the place of each in its environment is a very complex matter. The need to interface programs requires a collaborative approach from the outset of new production unit design.

The design must be analysed throughout as it is intended to implement a series of activities which, starting from a request for process automation (which can range from a simple vocal question to full specifications) to devise, write and finalise software programs ready for their delivery to the customer.

Generally speaking, software design involves 3 major phases:
- functional analysis or design *(⇨ Fig.3)*;
- specifications;
- design.

Analysis and design methods

The purpose of analysis and design methods is to formalise the preliminary stages of system development to match the customer requirements. This starts with an informal statement (requirements as expressed by the customer completed by questioning of operating experts such as future program users) and an analysis of any existing system.

The analysis phase serves to draw up a list of the results expected with regard to functions, performance, robustness, maintenance, safety, extension capacity, etc.

The design phase serves to describe, usually in modelling language, the future operation of the system in unambiguous terms to facilitate its building.

Current trends in automation (driven by its close relationship with information technology) point in the direction of object-oriented programming. This leads to many advantages: reliable code, reusability, knowledge protection, faster qualification (acceptance), etc.

Programming tools

All these constraints lead to the creation of a modern, innovating software workshop designed to achieve the required results.

The term integrated development environment (IDE) is used to mean a set of software programs which can themselves produce industrial automation programs.

The activities an IDE covers are usually:
- general project design, building stages or phases;
- data and program subset naming conventions;
- data structuring;
- assistance for writing programs in different languages;
- compiling or generation;
- assistance for tests and correction monitoring;
- subset libraries that can be reused in other projects;
- documentation;
- management of successive versions or variants of individual programs;
- assistance for commissioning.

An IDE facilitates collaboration between programmers and subsequent program maintenance by promoting the use of common methods.

11.5 Choice of technology

The technologies available for building automation system equipment are mainly electromechanical, pneumatic or electronic (PLC's, micro-computers, standard or specific electronic cards). Networks and field buses have gained ground in equipment construction and have a great effect on the choice of materials.

For more information, please refer to *Field buses* distributed by *Schneider Training Institute* or Cahier Technique N° CT197: *Field bus: a user approach*.

There are three choice criteria:

- feasibility criteria to eliminate technologies which could not meet the specifications;
- optimisation criteria designed to minimise overall costs during the equipment's lifecycle (procurement, implementation, flexibility, fixed assets, production management, maintenance, etc.);
- financial criteria for building the equipment at optimal cost.

Eventually, preliminary FMECA can be used to help select the best suited technology.

Choice of components

A range of constraints should be considered:

- ambient temperature (which may derate the material), dust, vibrations, etc.;
- coordination of devices making up the power outputs;
- discrimination between protection devices up to the main circuit breaker;
- requisite machine cycle time;
- number of operating cycles;
- category of use (AC-1, AC-3, etc.);
- standards (petrochemical, electrical, marine, etc.).

11.6 Equipment design

Computer-Aided Design

Software tools can be of great assistance in the field of automation system design. Apart from building the diagram, the designer can use them throughout the project, from the record of the customer's request for a quotation to commissioning and maintenance assistance.

This way of proceeding not only boosts productivity in system design, it also improves the quality of the diagrams and programs and facilitates their upgrading.

The main features of CAD software are:

Intelligent symbol database

Each symbol has a behaviour mode (master, slave), an electrical function (isolation, switching, etc.) and connection terminals. It is linked to a family of hardware (disconnectors, contactors, etc.) and an identification method. It supports the variable references offered by the software or entered by the user.

The database also ensures information consistency and guides the user during input.

A hardware database with all the technical and sales information to facilitate the choice of components and input of product lists, quotations and purchases.

Standardised templates (single-line definition, automation system structure, power and control diagrams, overall dimensions, product lists, etc.).

A diagram database (motor starter, power and control sub-units, hoisting movements, etc.).

It helps to respond quickly to a call for tender (single-line diagrams) and simplifies diagram drawing.

Electrical installation information management

- equipotential links;
- detection of existing numbers;
- short-circuit control;
- terminal block control;
- hardware identification;
- automatic creation and control of identity uniqueness;
- cross references;
- control of auxiliary contactor capacity and terminal numbers;
- overall dimension calculation assistance.

Overall dimension calculation

Three methods are used to define the overall dimensions of equipment.

Direct layout method

This method applies to small equipment on standard pannels offered by device manufacturers.

For instance, devices can be laid out directly on an installation sheet reproducing the frame of the Telequik® pre-slotted plate on a scale of 1. This helps to calculate the overall dimensions of the equipment quickly and easily.

Surface area calculation

This is a fast and accurate way to calculate overall dimensions.

The procedure is to make the calculation of the total surface area of the devices in the equipment (these are given in the catalogues), multiply the total by the following space factor:
- 2.2 for a maximum total of $34.2 dm^2$
- 2.5 for a total greater than $34.2 dm^2$

Some customers have specifications that may require a greater factor to leave space for any modification.

The result gives the total working surface area of the equipment.

The choice rules provided by manufacturers such as Telemecanique make it easier to find the references for plates, uprights, mounting rails and boxes based on the working surface. These rules also give the heat losses that can be dissipated by the enclosure walls.

Computer-aided

This is more aimed at services specialising in automation system equipment studies.

The installation tool in the CAD software offers overall dimension transfers based on the diagram and a Hardware Database.

Manufacturing file

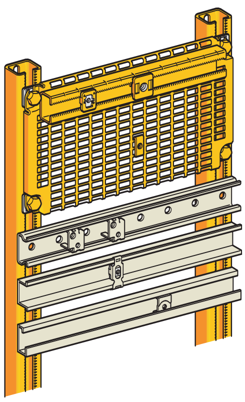
The complete file should be compiled before manufacturing starts. It defines:
- the list of all documents in the contents;
- boxes: installation, drillings, parts, etc.;
- cabinets: installation, framework plan, drillings, etc.;
- control stations: drillings, parts, etc.;
- electrical diagrams;
- programs;
- hardware list;
- overall dimension.

11.7 Building an equipment

Many electrical equipment manufacturers develop auxiliary components to implement their products. This is the case of the Telequik® system offered by Telemecanique *(⇨ Fig. 1)*.

This system contains all the products required for building equipment and ensures that the components of an automation system are quick and easy to implement.

Given their features, we have classified the products in it into four different functions to Enclose, Structure, Distribute and Connect.



↑ Fig. 1 *Telequick® pre-slotted plate by Telemecanique*

"Enclose" function

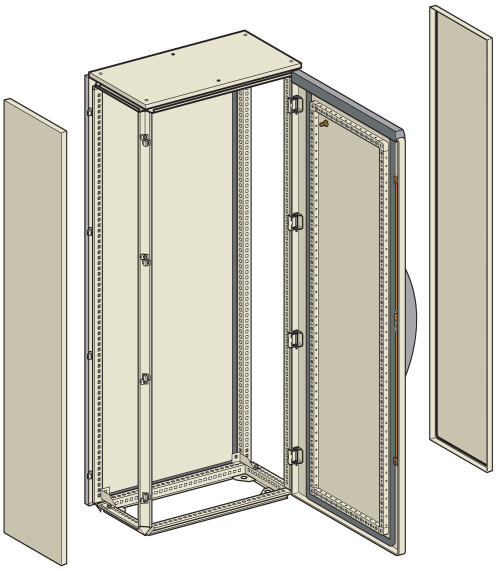
To protect the hardware from shocks, severe weather and ensure it can resist the most stringent conditions of use in industry, the equipment must be housed in boxes or cabinets. These should have all the features required for cutting down assembly and maintenance time.

Depending on the degree of protection needed, enclosures comply with defined standards and IP (International Protection) codes.

The IP code is described in the 60529 document published by the International Electrotechnical Commission.

It uses an alphanumerical method to define the level of protection the enclosures provide against the approach of dangerous parts, penetration of solid foreign bodies and the detrimental effects of water.

11.7 Building an equipment



↑ Fig. 2 *Telemecanique AA3 cabinet*

The first figure from 0 to 6 indicates simultaneously the protection of persons from dangerous parts and protection from penetration of foreign bodies.

The second figure, also 0 to 6, indicates protection from water splashes.

The additional letters indicate further protection such as internal baffles. Cahier Technique CT 166 *“Enclosures and levels of protection”* gives a detailed description of the codes and the stringency of the corresponding tests.

The builder is responsible for end product compliance with standards, but the enclosure manufacturer documentation must specify where the hardware must be fitted to ensure the stated levels of protection are maintained.

The installer who connects (wiring) and attaches the cabinets and in some cases adapts the auxiliary components (push buttons, measuring devices, etc.) must also ensure the specified level of protection is maintained.

Schneider Electric offers an entire range of boxes, cabinets and parts compliant with IP standards (⇨ *Fig. 2*).

“Structure” function

To bind the components together mechanically, there is a range of perfectly adapted products to assemble and attach automation system components firmly. Put together, these products make up the structure of the equipment and their assembly systems provide great flexibility of use, a wide choice of assembly options and significant cost savings in implementation.

“Distribute” function

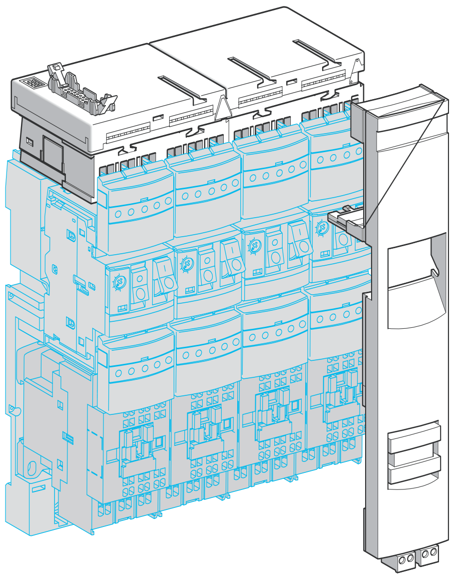
Electrical power distribution

When building equipment, product implementation must comprise safety, simplicity and fast assembly and wiring. Maintenance and any modification to the equipment must be easy to perform, with the least possible impact on operating continuity.

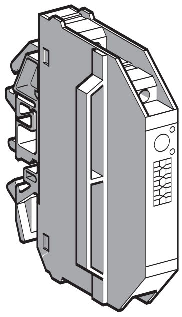
To meet these criteria, there are distributors basically designed to shift the main current to a number of secondary circuits (see the Schneider Electric general catalogue for more information).

Some models are designed as product supports so it is possible to intervene on live equipment (e.g. connection or disconnection of a motor starter unit).

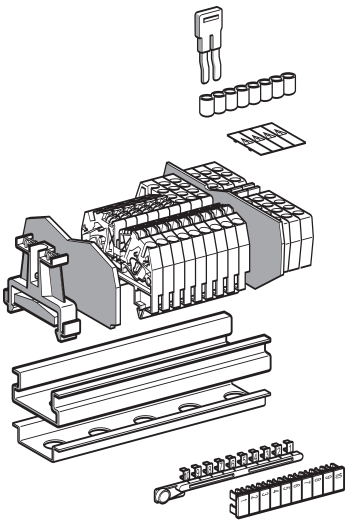
This is notably the case with the Telemecanique TegoPower technology (⇨ *Fig. 3*).



↑ Fig. 3 *Motor starter units built with Telemecanique TegoPower technology*



↑ *Fig. 4* *Interface ABS2*



↑ *Fig. 5* *Telemecanique terminal block*

- **Distribution of low signals**

Manufacturers' catalogues offer interfaces and connection systems for different control signals:
- discrete signal interfaces *(⇨ Fig. 4)*;
- analogue signal interfaces;
- temperature probe interfaces;
- wiring interfaces;
- peripheral automation system components;
- field bus interfaces.

- **"Connect" function**

This function covers the products required for wiring and connecting equipment.

- **Terminal blocks** *(⇨ Fig. 5)*

These comply with TEU standards and the major certification requirements. They are made of coloured nylon enabling them to be used at temperatures ranging from -30 to + 10°C.

Their fire-resistance complies with the standard NF C 20-455. They are identified by characters on clip-on strips and are designed for connecting conductors with a maximum section of 240 mm².

They cover all needs:
- a wide range of currents, from a few amperes (control, signal electronic circuits, etc.), to several hundred amperes (power connections);
- fixed or detachable single- or multiple-pole blocks;
- screwed, bolted, clipped, welded or spring connections;
- blocks for special functions such as fuse or electronic component holders, draw-out terminals, overload conductor connection, etc.;
- mounting on rails, pre-slotted plates or printed circuits.

- **Cable ends**

Cable ends have a number of advantages:
- easier wiring, as the copper sleeve is crimped automatically when the connection is fitted in the terminal;
- perfect resistance to vibration;
- wire strands cannot creep;
- timed saved in connection work;
- the same marker tag holders and markers for all cable sections. Each holder can take up to 7 marking rings (letters or digits).

Telemecanique cable ends also have:
- a different collet colour for each section;
- 3 sleeve lengths depending on the model.

There are insulated cable ends:
to standard NF C 63-023
- without tag holders for sections from 0.25 to 6 mm²;
- with built-in tag holders for sections from 0.25 to 6 mm²;
- with removable tag holders for sections from 4 to 50 mm²;

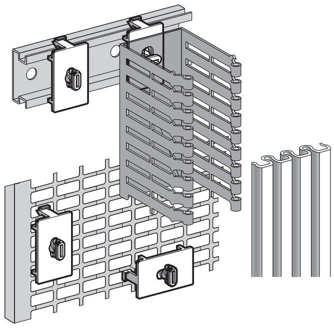
to standard DIN 46228
- collet colour per section different from the French standard;
- without tag holders for sections from 0.25 to 50 mm².

- **Cable clips and ducts**

Cable clips and ducts are designed to channel wires into horizontal and vertical layers on the same plane as the devices.

All the wiring is on the front facing, so repair work and alterations are made easier.

They are made of PVC and have no metal parts that can come into contact with the conductors they hold.



↑ *Fig. 6* *Telemecanique duct*

- **Ducts** *(⇨ Fig. 6)*

These have open slots in the sides and perforations at the back. They are fitted vertically or horizontally on feet with quarter-turn fixing devices. These can be clipped to combination or omega rails of 35 mm and to pre-slotted plates. Ducts are available in several sizes and can hold up to 700 wires of 1.5 mm^2. They are closed with covers that slot into them. The same tag holders can be used for ducts and cable clips.

11.8 Mounting

Automation system and distribution components are designed to be mounted on chassis or frame structures. This sub-section describes a few definitions, useful tips or rules and draws attention to the precautions to take in mounting work.

Chassis

This consists of two pre-drilled vertical uprights, with or without notches.

The device, depending on its mounting system, is either clipped or screwed to:
- horizontal rails;
- pre-slotted plates;
- solid plates;
- a combination of plates and rails.

Depending on the dimensions of the rails or plates and, above all, the mass of the device, it is advised to use:
- combination or omega rails of 35 mm;
- omega rails of 75 mm;
- "C" uprights to support the devices instead of horizontal rails;
- pre-slotted plates stiffened at the back with a horizontal rail.

Chassis are usually mounted in monoblock cabinets or boxes.

Frame

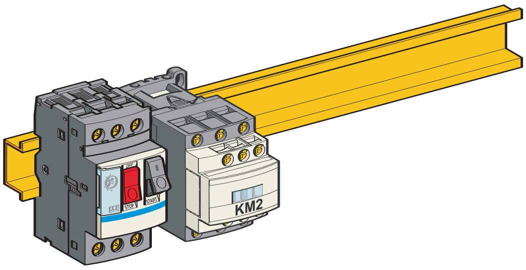
This is a unit consisting of one or more chassis side by side or back to back, held to the floor by a cross piece/foot or hung on the wall by the top of an upright. It can also be installed in and linked to a cabinet the upper part of which is equipped with horizontal busbars to power each chassis.

Devices on doors or front plates

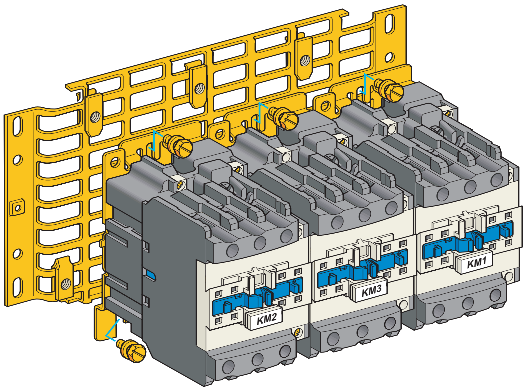
Certain control or viewing devices are mounted on the doors or front plates of enclosures. To maintain their ergonomics, they must be arranged according to rules which depend on their type (control or viewing) and their elevation from floor level.

The layout must take into account the number of parts to be placed:
- few parts: distributed along the horizontal axis of the area;
- many parts: distributed over the entire area.

Some doors and front plates have reinforcements or parts inside which restrict installation. The depth of parts on doors must be checked against the parts mounted on the chassis. The weight of these parts must also be considered.



↑ *Fig. 7a* *Mounting on omega rail*



↑ *Fig. 7b* *Devices screwed to pre-slotted plate*

Device mounting

The following general rule should apply when mounting and attaching devices to chassis and frames: attachment should always be possible from a front access. Since equipment is nearly always in a box or cabinet, such access makes it much easier to carry out any alterations or additions to it.

The *figures 7a and 7b* shows some examples of device mounting.

11.9 Device fitting tools

To ensure the requisite levels of protection and facilitate integration work, Schneider Electric offers software and products to simplify integration of push buttons and man-machine interfaces (Tego dial range).

The software helps to keep account of the ergonomics and mounting and attachment kits help to cut down study and fitting times considerably.

Wiring

The wiring procedure “by explanatory circuit diagram” works by systematic use of the device terminal markings represented on the circuit diagram.
It applies to the power and control circuit wiring of all equipment with contactors, regardless of complexity.

This wiring procedure saves time for the user.

The circuit diagram is noted for:
- execution speed: time saved in design;
- clarity: simple illustration of electrical circuits;
- easy understanding: intuitive wiring;
- operational efficiency: easy comprehension, searches, modifications and servicing.

It can be accompanied by a hardware layout and installation plan to help locate components and by an external connections diagram.

Wiring with the help of the circuit diagram

Whatever the power or control circuit, the wiring engineer picks out the device terminal markers on the circuit diagram and connects the relevant sections between the corresponding markers in the equipment.

Linking examples:
- terminal 2 of disconnector Q1 to terminal 1 of fuse F1;
- terminal 22 of contact KM3 to terminal 57 of contact KA1.

11.10 Platform tests

The purpose of platform tests is to correct any errors made when building the equipment and make adjustments prior to commissioning. The following points must be checked:
- the hardware is the same as specified in the plans and is correctly mounted;
- the wiring is the same as in the diagrams;
- operation complies with the specifications.

Some of these checks must be made with live equipment, so the following points are mandatory:
- platform tests must always be run by trained personnel qualified to work with live electrical equipment;
- all the requisite precautions must be taken to ensure the safety of persons in compliance with current legislation..

Hardware compliance inspection

This is an inspection of the physical aspect of the equipment and comprises the following points:
- presence of contractual documents (diagram, product list, installation, etc.);
- the hardware mounted on the chassis is the same as stipulated in the documents;
- the hardware is laid out and mounted as stipulated in the documents;
- the hardware has not suffered any mechanical damage;
- component markings appear on the devices and door-mounted components are marked by tags;
- the voltage of all devices is the rated voltage;
- lamp bulbs are in place and use the rated voltage;
- device ratings are the same as stipulated in the diagrams;
- fuse ratings and types are compliant (usually, appropriate fuses are installed by the platform engineer);
- the terminal blocks are properly marked, mounted and of the right section for easy connection of external wiring. It is important to check that the frame terminals are adequately insulated from adjacent terminals (correct position of latching strips);
- requisite distances between terminals, devices, frames and safety limits are observed;
- the component characteristics are the right ones for their use;
- construction rules or particular contract specifications have been followed.

Proof that the inspection has really been undertaken is to be given in a special document or mentioned on the installation diagram and signed by the operator.

Connection clamping checks and preliminary adjustments

Before proceeding to electrical tests on the equipment, all the control and power connections must be checked to see if they are properly clamped. This operation is important because a poorly clamped connection can cause problems: abnormal heating, voltage drops or short circuits.

The operator can then adjust the value of the trip current of the thermal overload relays by displaying the current indicated on the diagram beside the motor power on the adjustment dial of each of them.

Insulation test

The quality of insulation is measured in meg-ohms (= 10^6 Ω) with a megger.

Insulation is measured:
- between two conductors insulated from each other;
- or between a conductor insulated from the earth and frames and from earthed frames.

Sensitive devices and circuits are disconnected before checking the insulation of each circuit's wiring between terminals and between terminals and the earth. Likewise, the insulation of break device conductors is checked on both sides.

The *figure 8* gives the voltage values for measuring insulation and the isolation resistance to be reached.

Rated voltage of circuit	Insulation test direct voltage	Isolation resistance 1n MΩ
< 48 V	250 V	Equal to or higher than 0.25
Voltage from 48 to 500 V	500 V	Equal to or higher than 0.5
Voltage higher than 500 V	1 000 V	Equal to or higher than1

↑ *Fig. 8* *Insulation voltage test*

Dielectric tests

These are designed to test the dielectric rigidity of a device unit at an alternating voltage defined according to the circuit's rated insulation voltage.

Dielectric rigidity is expressed by resistance to a test voltage applied between active conductors and the chassis frame. The test is considered satisfactory when there is no breakdown or flashover.

The device used is a flashover bridge delivering an alternating voltage that can be adjusted to a frequency between 45 and 55Hz. It can provide high voltage with a very weak current.

When it is applied, the test voltage must not exceed 50% of the value indicated in *figure 9*.

Rated insulation voltage	Dielectric test voltage (RMS voltage)
< = 60 V	1 000 V
Voltage from 61 to 300 V	2 000 V
Voltage from 301 to 660 V	2 500 V

↑ *Fig. 9* *Dielectric voltage test*

It is then gradually increased until it reaches the specified value a few seconds later. This voltage is maintained for one minute.

When the equipment includes electronic devices, dielectric tests cannot be run afterwards but must be run during the mounting and wiring process to prevent any destruction.

11.10 Platform tests

Power circuit check

This check is designed to ensure the power wiring complies with the diagram and is run with the equipment turned off.

In most cases, it is run with a test lamp.

Control circuit check

Wire-by-wire check

This check is designed to ensure the control circuit wiring complies with the diagram and is usually run with the equipment turned on. It is also used to check that the devices work properly.

To run the tests safely, the power and control circuits must be completely separated from each other for the entire duration. Furthermore, it is advisable to insulate electronic units such as speed controllers and PLC's to prevent any voltage injection that could cause partial or total destruction.

Wiring checks are made "line by line". The action of each contact must be checked, including that of external contacts by short-circuiting the corresponding terminals.

Electrical continuity must be checked.

For small equipment, wire-by-wire checks can be run with the power off, using a test lamp or megger.

General test

The general test involves simulating all the operating phases of a machine or process in the order they are supposed to run and checking the servosystems and safety.

An adequate power supply must be provided and the interconnections and connections made with the test benches which replace the external control auxiliaries by switches, push buttons, etc.

The purpose of the general test is to ensure that the equipment operates as described in the specifications.

It is also designed to check the effect of an operating error in machine or process control, of an impaired external control element (limit switch, detector, etc.).

The programs are loaded in the PLC's and tested as fully as possible by simulating discrete inputs by contacts and analogue inputs by signals. This simulation is used to correct any programming error and substantially reduce the time required for commissioning.

For equipment with electronic speed controllers, simulation should include a dynamic test using the installation's motors or, failing this, a test motor, preferably with comparable ratings.

It is advisable to draft a test report mentioning the adjustments (values) and alterations (programs and hardware) made, as well as any elements that could not be tested or were only partly tested.

This document will help to make commissioning work easier.

The diagrams, listing and product lists should be altered to give an exact description of the equipment that is to be commissioned.

Cabinets and boxes are unwired before shipping. If necessary, heavy parts are wedged to prevent frames and cabinets from warping during transport.

The bases of cabinets should be thoroughly cleaned to prevent any foreign bodies (washers, wires, etc.) from getting into the devices.

11.11 Equipment commissioning

All devices leaving the factory are checked by experts before shipping and adjusted or calibrated with extreme precision.

It is advisable not to make new adjustments, except to overload relays and timed auxiliary contacts, which can be adjusted on site to suit operating conditions.

As for platform tests, on-site commissioning of equipment includes work done with it switched on. The same rules therefore apply: supervision by qualified authorised personnel, compliance with safety rules.

Installation

Upon receipt of equipment

Check that:

- the enclosures have not received any shocks;
- the mobile part of the rotating contactors has not been warped or shifted;
- no foreign bodies have entered the air gap in the magnetic circuit, between the contacts or terminals;
- the mobile part of the contactors and disconnectors and the overload relay trip devices work freely;
- the closing devices (boxes, cabinets) work properly;
- seals are tight (for proofed hardware);
- the control and signalling auxiliaries and the measuring devices on the doors are in good condition;
- the shipment includes up-to-date diagrams, commissioning instructions, operator manuals and any platform test reports.

Before connecting external conductors:

- check the voltage and frequency of the power supply to the power and control circuits;
- check that the type and gauge of fuses and protection relays are properly adapted to the receivers to protect.

Attaching and connection equipment

- work out the section of the connection cables according to the current absorbed by the machines under control. To prevent voltage drops, increase the section of the wires and cables powering the control and power circuits when the line is long or when very low voltage is used;
- on units with watertight boxes, the conductor duct must be inserted into the rubber seal of the box. This must be tightened to immobilise the cable completely;
- external connections must be made in strict compliance with the diagram;
- current installation rules must be followed. For this purpose, there is a marked terminal on the boxes, cabinets and control auxiliaries for connecting frames to the external ground conductor;
- for devices used in highly corrosive or tropical atmospheres, it is advised to cover the terminals with a layer of protective varnish after connection.

Adjusting thermal overload relays

The graduations in amperes on the dial correspond to the current absorbed by the motor. Adjustments are made by displaying the value etched on the dial opposite the index, which corresponds to the absorbed current (look at the full load current corresponding to the mains voltage on the motor rating plate).

For a star-delta starter, when the relay is directly connected in series with the motor windings, the adjustment value should be $I / \sqrt{3}$, I being the current absorbed by the motor.

11.11 Equipment commissioning

Thermal overload relays are compensated, so there is no need to make adjustments for ambient temperature within the limits indicated on the technical data sheets.

These adjustments are usually made on the platform and are indicated in the test report.

When the power line and all the external power and control circuits are connected, general tests of the equipment can be made. These are run in two steps:

No-load test

This test is run to check that all the connections (control and signalling auxiliaries, sensors, safety switches, etc) have been made correctly and in compliance with the diagram. To run it, the power to all the receivers must be cut off:

- by removing the fuse cartridges protecting the power circuit from their base;
- or by powering the control section only and leaving the power section off.

When the control circuit is powered, an action on the starter control auxiliary should stop the contactor(s) it governs and, on more complex equipment, start the automatic cycle. At this point, it is advised to operate external devices manually (particularly safety devices) or simulate their operation, then deliberately and methodically trigger every control and operation anomaly to check the efficiency of the control, servosystem, safety and signalling circuits.

On-load test

Now, turn on the power circuit to run a general on-load test to check the exactness of the connections and receiver operation. This test can be completed by a series of further ones to check the automatic equipment governs the installation's mechanical functions properly.

Successful commissioning is the result of the operator's experience along with the contents of the equipment file (automation system lists, commissioning instructions, device manuals, etc.).

Troubleshooting

The wide variety of automation equipment makes it impossible to define a troubleshooting procedure that applies to all diagrams.

Experience and knowledge of the equipment and its functions are indispensable to an efficient troubleshooting.

Knowledge of the FMECAs carried out at the design stage can be very useful when seeking the reason for failures.

11.12 Equipment maintenance

At the design stage, FMECAs are used to define maintenance operations and their intervals:
- motor brush replacement when applicable;
- filter cleaning;
- wear part replacement;
- consumable item provisions, etc.

Electronic and electromagnetic devices require practically no maintenance. However, a few important points should be noted.

Electromagnet in the contactor

If the magnetic circuit is noisy, check:
- the mains power voltage. An electromagnet vibrates when it is powered by an alternating voltage lower than the one it is designed for;
- there is no foreign body between the mobile and immobile parts of the magnetic circuit;
- the state of ground surfaces. These should never be painted, scraped or filed. If they are very soiled, clean them with spirit or appropriate solvent.

Contactor coil

If a coil has to be replaced (such as when the control circuit voltage changes), the new coil must be defined according to the actual control circuit voltage. It then ensures:
- closing of the contactor when the voltage reaches 85% of its rated value;
- opening of the contactor when the voltage drops below 65% of its rated value;
- permanent tolerance of voltage corresponding to 110% of the rated value.

A coil can be damaged due to:
- incomplete closure of the magnetic circuit caused by a mechanical incident or a control circuit voltage of less than 85% of the rated value. In alternating current, this lowers the reluctance of the magnetic circuit and, in direct current, destroys the efficiency of the consumption control system where the contact has not opened. It also prevents there being adequate pressure on the poles, which overheat and can weld if the current crossing them is the one absorbed by a motor during starting;
- a poorly adapted control circuit;
- a power voltage greater than 110% of the rated value.

In all cases, the coil will deteriorate if the energy dissipated by Joule effect is higher than normal. To prevent such incidents, use coils adapted to the voltage measured at the equipment's power supply terminals.

Contactor poles

Knowledge of controlled power and the category of use (such as disconnecting a running squirrel-cage motor) helps to ascertain the electrical durability of the contacts in an individual contactor or to choose a contactor on the basis of the intended operations.

11.12 Equipment maintenance

□ Block contactor

Block contactor poles need no maintenance.

For example, in category AC-3, a contactor powering a compressor motor that starts 6 times in an hour and operates 24 hours a day will have a lifetime of: 2,500,000 = 17,360 days, i.e. about 50 years without maintenance.

Contacts that have made many breaks may appear to be worn.

Only regular checks of the compression rate or monitoring, with some calibres, of the general wear indicator can ensure the wear rate is properly ascertained.

When in use, never adjust the compression rate. When this ranges from 20 to 50% of the initial rate, the contacts must be changed.

After this operation:
- the contacts must be aligned according to the initial compression rate;
- it is advised to scrape the sides of the blow-out chambers;
- it is indispensable to check the screw tightening torque.

□ Auxiliary contactor contacts

No maintenance and no adjustment except the duration of timing on timed auxiliary contacts.

□ Thermo relays

No maintenance. The only possible intervention is adjustment of the trip current value which depends on the current absorbed by the receiver.

□ Enclosures

Grease hinges and the closing device from time to time.

On sealed boxes and cabinets, check the efficiency of sealing devices (seals, cable glands, cable boxes).

Clean filters with a vacuum cleaner, never use compressed air.

□ Radiators of electronic devices

Devices that use electronic power components are fitted with radiators, usually with forced ventilation.

Depending on the environment and any dust in the atmosphere, clean the fins periodically to prevent them from clogging.

■ NEVER

- file or grease contacts;
- alter a part or replace it with an improper spare;
- rearm an overload relay without having found and eliminated the cause of tripping;
- replace a fuse and repower the equipment without having remedied a fault;
- leave a cabinet or box open unnecessarily, especially in a dusty atmosphere;
- use inappropriate solvents.