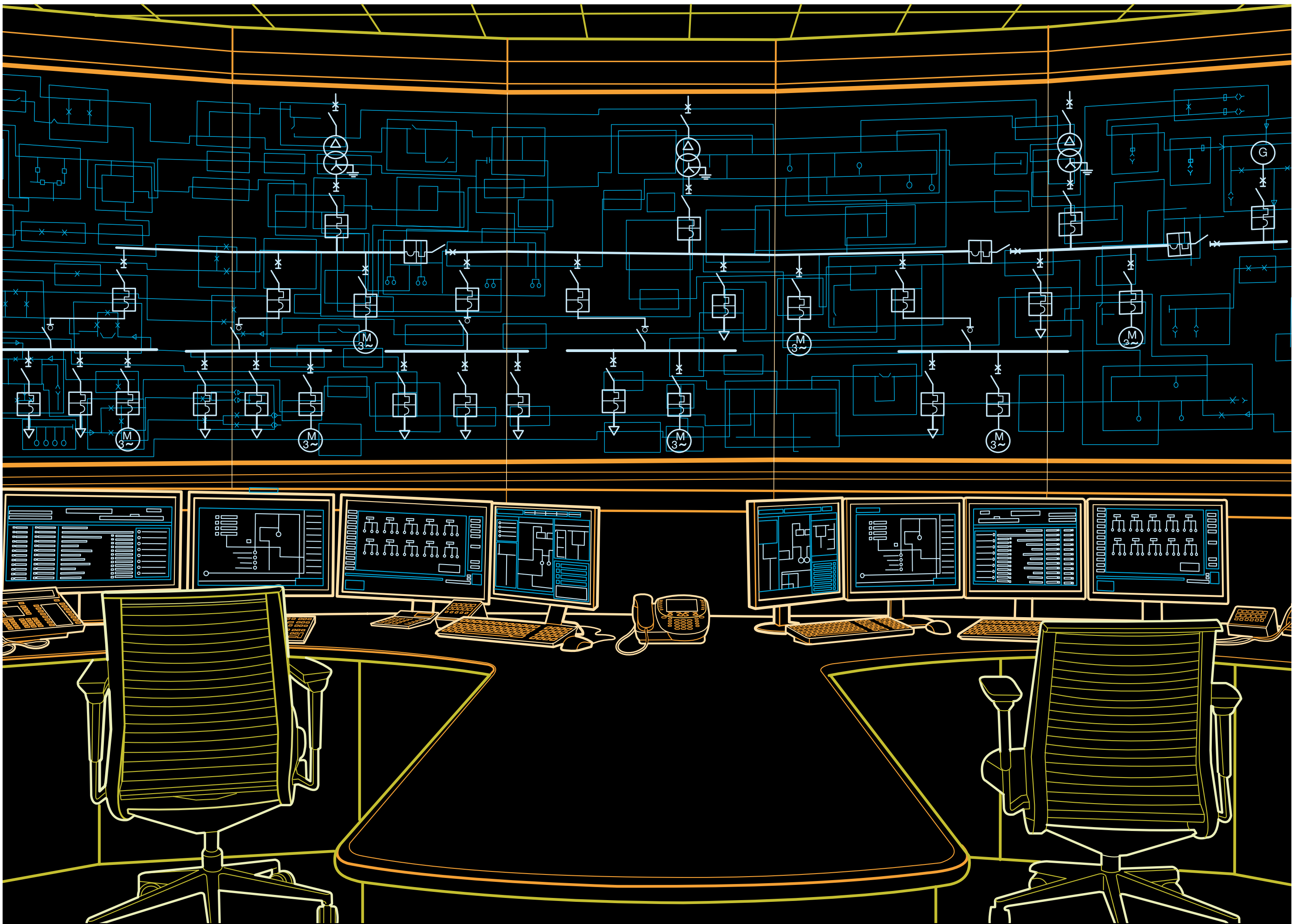


Technical Application Papers No.9
Bus communication with ABB circuit-breakers

Power and productivity
for a better world™

Bus communication with ABB circuit-breakers

Index

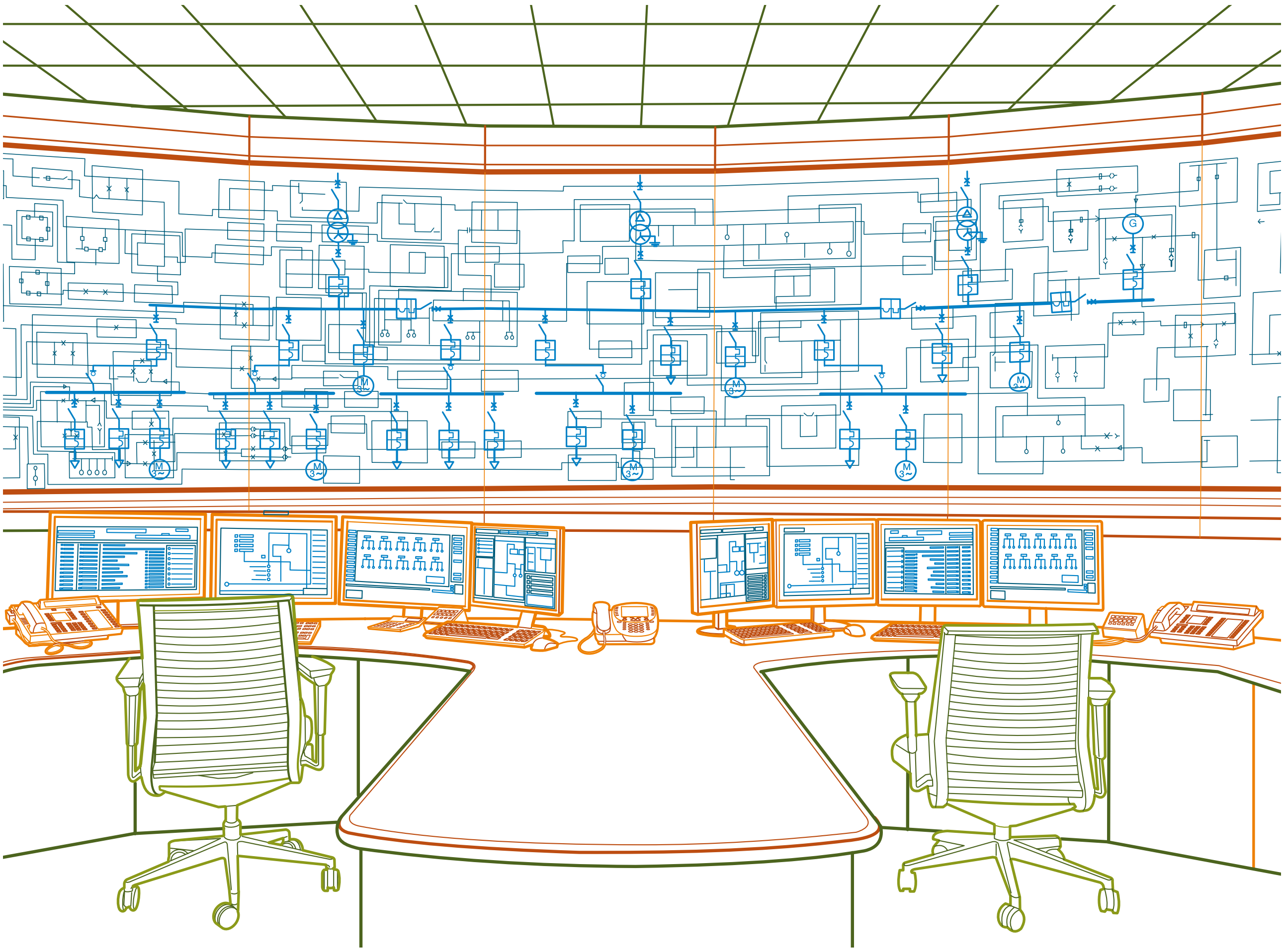
1 Introduction

Due to the ever growing use of automation and supervision systems for industrial processes, for a better management of the electrical and technological plants, circuit-breaker manufacturers have been driven to implement - on the electronic trip units - the dialogue interfaces for bus communication with control devices such as PLC, PC or SCADA.
In this way, automatic circuit-breakers are used not only for switching and protection but also for the supervision and control of electrical distribution plants. This Technical Application Paper has the main purpose of introducing the reader to the basic concepts of:
- communication networks and protocols
- dialogue between microprocessor-based "intelligent" devices

and describing the main functions of the electronic trip units which allow ABB circuit-breakers to communicate via bus. In particular, this document is aimed at giving the essential information for the correct choice of the trip units, of the communication modules, of the accessories and of the software necessary to integrate ABB circuit-breakers in the supervision systems of electrical and technological installations (e.g. manufacturing lines of industrial processes).

This document is divided into five main parts:
- introduction to digital communication and basic concepts regarding communication protocols;
- supervision of electrical distribution plants;
- ABB solution for field bus communication (Modbus RTU, Profibus DP and DeviceNet) and the rules for the arrangement of the Modbus RS-485 network;
- front panel interface HMI030;
- solution to integrate ABB circuit-breakers into the Ethernet networks with Modbus/TCP protocol;
- some application examples regarding ABB SACE circuit-breakers used for the automated management of electrical distribution plants.

Seven annexes are included in this document.
Annex A contains the tables with the main information, the measures and the alarms put at disposal by the trip units. The other Annexes deal in details with the functional and applicative aspects of the products and of the accessories (communication modules, measuring modules, auxiliary contacts in electronic version, connectors and motor operators) necessary for the bus communication functions of ABB automatic circuit-breakers. In particular, Annex C includes the indications to connect the circuit-breakers to a Modbus RS-485 network.

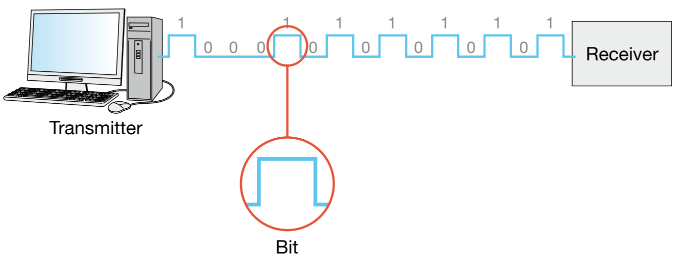


2 Digital communication

Digital communication is a data exchange (in binary form, that is represented by a string of bits[1]) between "intelligent" electronic devices provided with suitable circuits and interfaces.
The communication usually occurs serially: the bits which constitute a message or a data packet are transmitted one after the other over the same transmission channel (physical medium).

[1] A bit is the basic information unit managed by a computer and corresponds to the state of a physical device, which is represented either as 0 or as 1. A combination of bits may indicate an alphabetical character, a numeral, give a signal or carry out switching or another function.

Figure 1: Bit sequence



The apparatus which have to exchange data and information are linked together in a communication network.
A network is usually constituted by nodes interconnected with communication lines:

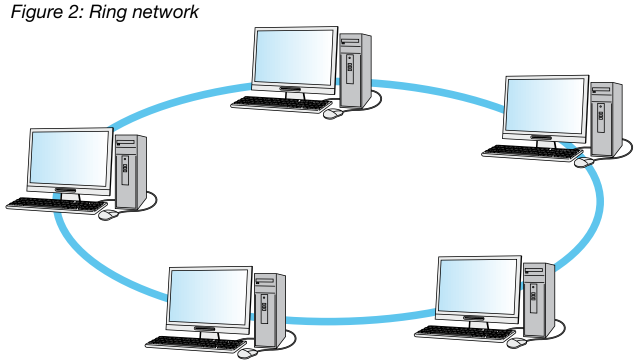
- the node (an "intelligent" device capable of dialogue with other devices) is the point of data transmission and/or reception;

- the communication line is the linking element between two nodes and represents the direct path followed by the information to be transferred between the two nodes; in practice it is the physical medium (coaxial cable, twisted pair cable, optical fibers, infrared rays) through which data and information are transmitted.

The main communication networks can be classified according to the following topologies:

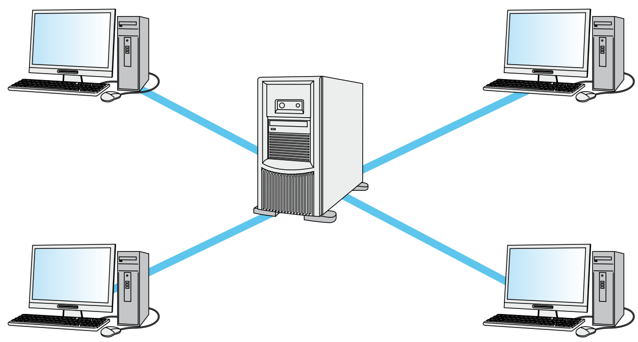
- Ring network
Ring networks are constituted by a series of nodes (in Figure 2 these are represented by personal computers) interconnected to get a closed ring.

Figure 2: Ring network



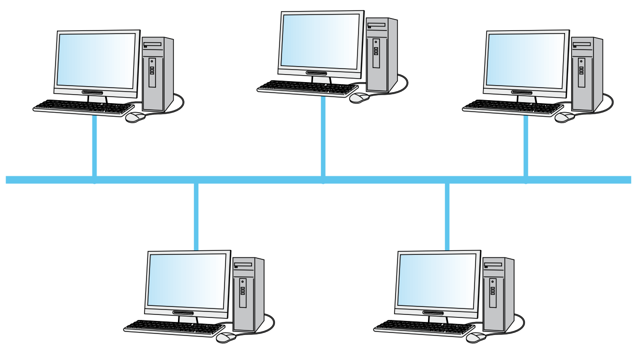
- Star network
Star networks are based on a central node to which all the other peripheral nodes are connected.

Figure 3: Star network



- Bus network
The bus structure is based on a transmitting medium (usually a twisted cable or a coaxial cable) in common for all the nodes which thus result to be connected in parallel.

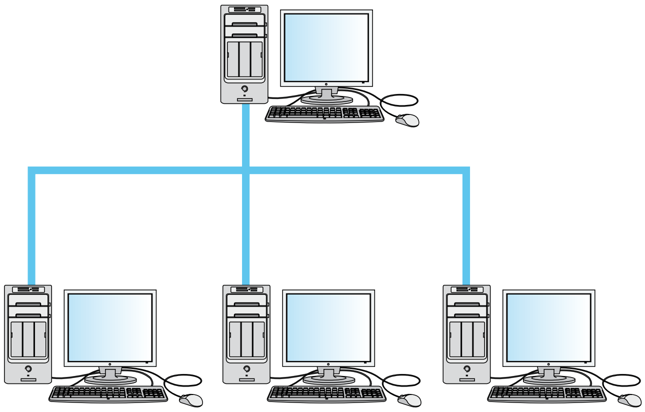
Figure 4: Bus network



These are some examples of process management where a dialogue is required between the devices in a communication network:

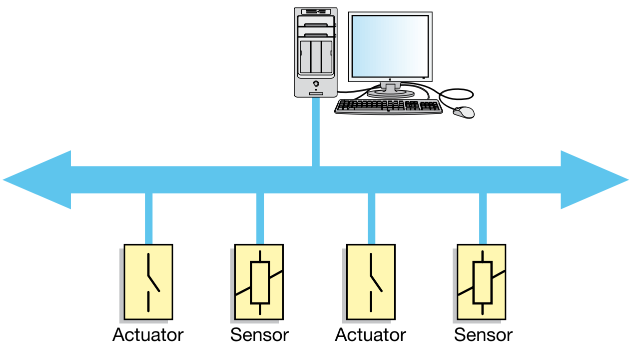
1) data interchange between the personal computers, in a company or a firm, linked through a LAN network[2].

Figure 5: Example of LAN network



2) data and commands transceiving between a supervision system and the field devices (sensors and actuators) of an automation system, for the management of an industrial process.

Figure 6: Example of a supervision system for industrial process management



To manage the data traffic over the network and to allow understanding between two communicating devices, a communication protocol is necessary.
The communication protocol is the whole of rules and behaviors which two elements must comply with to interchange information; it is a definite convention associated to the data exchanged between the communication partners.

[2] *LAN (Local Area Network): local network (e.g.: Ethernet) linking together personal computers and terminal stations physically near, for instance located in the same office or in the same building.*

The protocols used to make the different devices in industrial applications communicate are very numerous and vary according to the communication requirements of each application; these may be:

- the quantity of data to transmit;
- the number of involved devices;
- the characteristics of the environment where the communication takes place;
- the constraints of time;
- the criticality of the data to be sent;
- the possibility, or not, to correct data transmission errors;

and more.
There is also a further wide variety of protocols used to put into communication data processing apparatus, such as the computers and their peripherals.

In the following chapters these protocols are not dealt with, but the discussion is limited to a description of the protocols dedicated to industrial communication in fieldbuses, that is, those networks used to exchange information between a control system and the field devices (the sensors and the actuators provided with an advanced communication interface directly interacting with the physical process to be kept under control).

In particular, the concepts of communication, supervision and control shall be applied to the management of the low voltage electrical energy distribution installations.

2.1 Communication protocols

The protocols currently used in industrial communications are very complex.
In order to simplify their description, it is usual to separate the operation levels. In any protocol three levels can be distinguished: a physical layer, a data link layer and an application layer. Each layer refers to a functional aspect of communications and in particular:

- the physical layer specifies the connection between the different devices from the point of view of the hardware and describes the electrical signals used to transmit the bits from one device to the other; for instance, it describes the electrical connections and the wiring systems, the voltages and the currents used to represent the bits 1 and 0 and their duration. In the industrial protocols, the physical layer is generally one of the standard interfaces type RS-232, RS-485, RS-422 etc.;

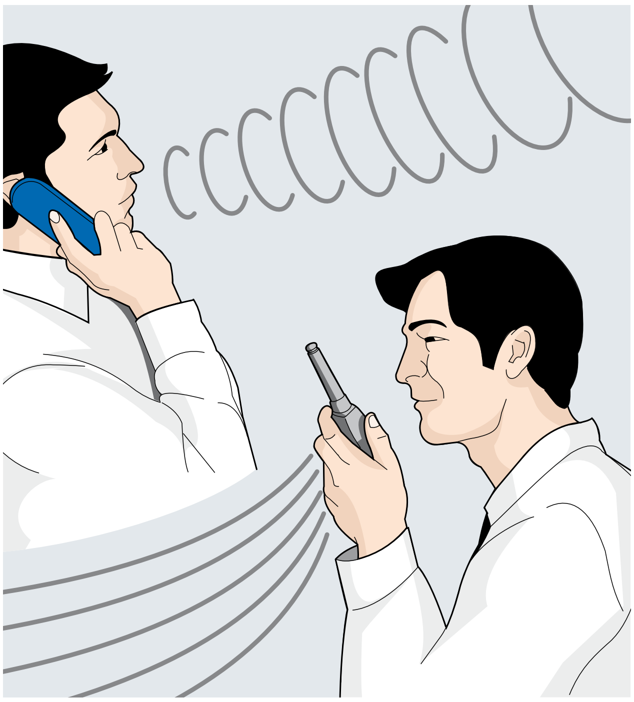
- the data link layer describes how the bits are grouped into characters and these into packets, and how any error is detected and possibly corrected. If necessary, it defines also the priorities to comply with to gain access to the transmission medium;

- the application layer describes what are the transmitted data and what is their meaning with reference to the process under control. It is the layer in which it is specified which data shall be contained in the data packets transmitted and received and how they are used.

Generally speaking, these layers are independent one from the other; by applying this concept of layers to the communication between people, it is possible to agree on talking either on the phone or on transceivers (physical layer), on speaking English or French (data link layer) and on the subject matter of the conversation (application layer).

To get a successful communication between two entities, all the layers taken into consideration shall correspond to each other; for instance, when using the telephone we could not talk to whom is using a radio, we could not understand each other if we use different languages, etc.

Figure 7: Impossibility of communication between transceiver and telephone



Without aiming at a thorough description of the existing protocols, we wish to point out some of the characteristics of the communication system through a brief description of the three mentioned layers.

2.1.1 The physical layer

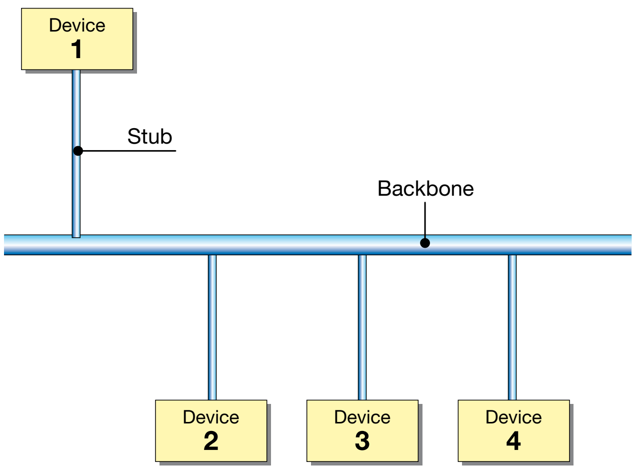
When taking into consideration the physical layer it is possible to distinguish between:
- wireless systems, which use as physical medium radio waves, infrared rays or luminous signals propagated in free space;

- wired or cabled systems, whose signals are transmitted over cables (or optical fibers).
  Among the latter there are:

  - point-to-point cabling systems, in which each section of cable links two devices and is used exclusively for the communication between them (a typical example is represented by the communication PC-printer). This communication can be full-duplex type, when the two devices can transmit simultaneously, or half-duplex, if they can transmit only alternately;

  - multipoint (called also multidrop) cabling systems in which many devices share in parallel the same communication cable.
    Among multipoint systems, particular importance have those with bus connection, where a main cable (backbone) without stubs or with very short stubs connects in parallel all the concerned devices.

Figure 8: Multi-drop system with bus type connection



The physical layer interfaces mostly used in industrial networks are RS-232 for point-to-point connections and RS-485 for multipoint connections.

2.1.1.1 RS-232 and RS-485 interface

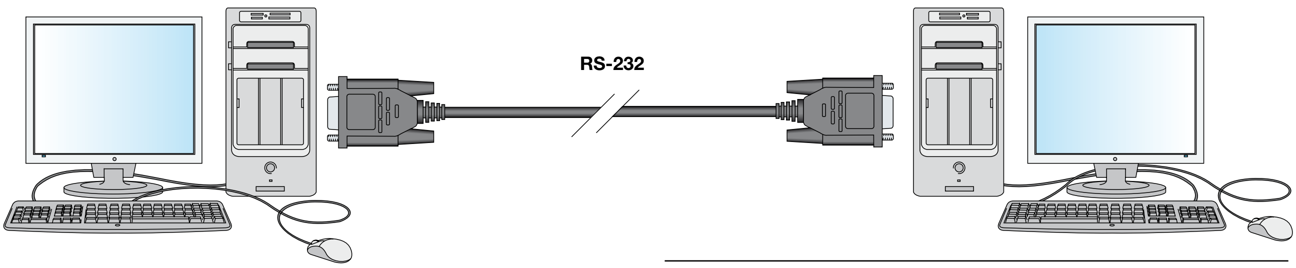
When speaking of physical layer we have:
The RS-232 interface, which is so common in personal computers to be known as “serial port”, is an asynchronous point-to-point serial communication system allowing full-duplex operation.

Figure 9: RS-232 9-pin serial connector

Figure 10: RS-232 9-pin serial cable

Here is an easy description of its features:
- “serial” means that the bits are transmitted one after the other;
- “asynchronous” means that each device can send only one character or byte separated by long or short intervals of time as needed;
- “point-to-point” means that only two devices can be interconnected according to this mode.
  When using the RS-232 interface to connect more than two devices, each pair shall have at its disposal an independent channel with two dedicated ports.

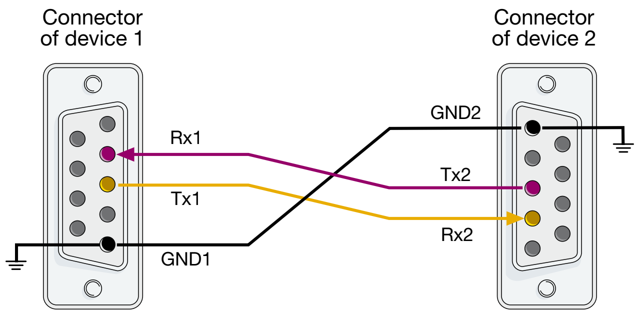
Figure 11: Point-to-point connection between two PCs



- “full duplex” means that the devices can transmit and receive the data simultaneously.
  Full duplex operation is possible because there are two separated electrical connections for the both directions in which the data can flow.

The bits are transmitted as voltage values from the transmission terminal (Tx) of one device to the receiving terminal (Rx) of the other device. These voltages are referred to a common ground conductor connected to the corresponding GND pin of the two devices.

Figure 12: Basic links for the communication between two devices with RS-232 interface.



Therefore, for the connection, minimum three wires (Tx, Rx and GND) are necessary: it is possible to use more links to regulate the data flow (e.g. to signal when a device is ready to transmit or to receive).
These operations, which constitute the handshaking and flow control[3] processes are not the subject of this technical paper. Each character flowing over the serial cable is constituted by:
- one or more start bits to inform the receiver about the arrival of a new character (being RS-232 an asynchronous interface, it is impossible, for the receiver, to know when a character has been transmitted and therefore it is necessary to signal in advance the start of the frame);
- a certain number of data bits (e.g. 8);

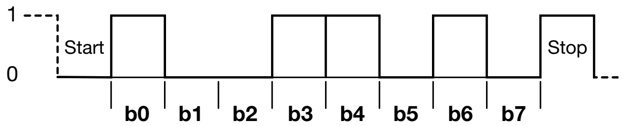
[3] *Flow control: method of controlling the flow of information.*
Handshaking: exchange of pre-established signals between two devices so that a correct communication is achieved. Thanks to this signal exchange, the devices inform that they have some data to transmit or that they are ready to receive data.

- an optional parity bit, used to detect whether among the transmitted bits there is a wrong one (in positive case the whole character is considered not valid and discarded). The parity bit, if used, can be configured in even or odd mode;
- one or more stop bits to signal the end of the transmission.

All the listed bits have the same length: the configuration of the serial interface is such as to transmit a definite number of bits per second (bps or baud). The transmission speeds are standardized and by tradition multiples of 300 bits per second are used. For instance, a device could transmit at 9600, 19200 or 38400 bauds, that is bits per second.
For a correct communication it is necessary that the two devices use the same settings: baud rate (data transmission speed), number of data bits, start bits and stop bits, presence or not of the parity bit and, if used, the mode (even or odd).
If this does not occur, no character is recognized correctly and consequently the transmission of data is impossible.

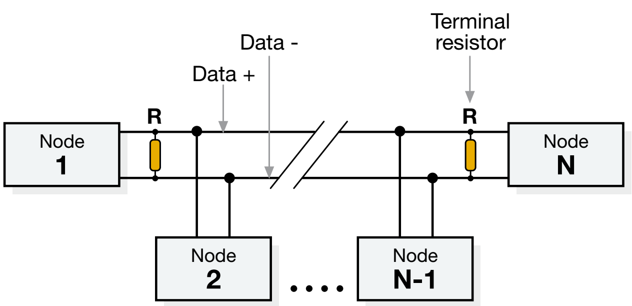
For instance, in the bit frame of Figure 13, it is possible to identify:
- 1 start bit
- 8 bits (b0….b7) constituting the character (the transmitted data)
- 1 stop bit.

Figure 13: 8-bit character



The RS-485 interface differs from RS-232 in the electrical and connection characteristics. Its main advantages are: the possibility of implementing multidrop[4] communication links, that is between more than two devices (see Figure 14) and the best immunity from electrical disturbances.

Figure 14: Multidrop system with bus connection on RS-485



These features make of RS-485 the most used interface in industrial environment, from the first versions of Modbus (in the Sixties) to the more modern Modbus RTU, Profibus-DP, DeviceNet, CANopen and As-Interface.
With RS-485, all the devices are connected in parallel on a single bus constituted by two connections, called: Data+ and Data-, or A and B or also Data1 and Data2, according to the different manufacturers of devices.

The used signals are differential: that is the bits are represented by the voltage difference between Data+ and Data-. The conductors are twisted and kept near one to the other so that the electrical disturbances affect them with equal intensity and the voltage difference is altered as less as possible.
When a device is not transmitting, it prepares for "reception", showing a high impedance on the communication port. The Standard RS-485 (EIA/TIA-485)[5] sets some limits on the input impedance and defines some requirements for the current/power that each device shall be able to transfer on the line when it conveys data.
In particular, in compliance with the prescriptions of the reference Standard, a correct data transmission is possible if, at the most, 31 devices "in reception mode" are connected on the line. As a consequence, in compliance with the Standard prescriptions, RS-485 guarantees that the communication can be carried out correctly with maximum 32 devices linked to the bus and that in each communication cycle, one device is in "transmission mode" and the other 31 are "in reception mode".
In fact, since all the devices are connected in parallel on a single bus, only one of them can transmit at a time, otherwise the signals overlap thus becoming unrecognizable.
The interface RS-485 does not include any mechanism aimed at defining which device has the permission to transmit; this task is demanded to the higher layers of the protocol used.
The structure of each transmitted character, its duration and the possibility of transmission configuration are the same as previously seen for the serial interface RS-232; for instance, there can be a data transfer set at a speed of 19200 baud, with 1 start bit, 1 stop bit and 1 parity bit used e.g. in "even" mode.
All the devices connected to the same bus must have the same settings in order to intercommunicate.
In industrial automation and energy distribution, the most part of the communication networks are realized with bus technology and the most used physical layer is the interface RS-485.

[4] *In principle, in a multidrop connection, the devices are linked in parallel to a main cable.*

[5] *EIA/TIA-485 "Differential Data Transmission System Basics" is the document which describes the Standard RS-485, which represents the main reference for all the manufacturers.*

2.1.2 Data link layer

As regards the data link layer, we speak of master-slave protocols when one of the devices (the master) has the task of controlling and managing the communication with all the others (slaves). Instead, we speak of peer-to-peer systems when such hierarchy does not exist and the devices gain access to the communication medium equally (in such case the protocol includes the procedures to manage the turns and the access priorities to the communicaton medium, a typical example is Ethernet).

Among the most common communication protocols there are:
- Modbus RTU, the most common connection protocol for electronic-industrial devices;
- ProfiBus-DP, used for field communication with intelligent sensors and actuators, generally with fast and cyclic data exchange between field apparatus and controllers;
- DeviceNet, also used to interface apparatus and controllers (PC, PLC);
- AS-i, for the communication with very simple sensors, such as limit switches, or switching devices (e.g. push buttons).

2.1.3 Application layer

The application layer gives a meaning to the transferred data, that is, it associates commands (e.g.: open/close the circuit-breaker) or a number (e.g.: voltage values) with the data in binary format interchanged by the devices over the communication network.
For instance, suppose to use the Modbus protocol for remote reading of the current values stored in a Tmax circuit-breaker equipped with PR222DS/PD trip unit.

Each trip unit stores the values of the quantities and of the parameters in dedicated registers; these registers can be reading only (e.g. register of current measures) or reading and writing (e.g. register for the setting of the curves and of the trip thresholds of the protections)[6].

In the PR222DS/PD, the currents are stored in the registers starting from the number 30101.

Figure 15: Registers of PR222DS/PD with run time current values

No. of register	Content of the register	Meaning of the content
30101	198	IL1 Current in the phase 1 [A]
30102	298	IL2 Current in the phase 2 [A]
30103	447	IL3 Current in the phase 3 [A]
30104	220	ILN Current in the neutral [A]

When the master unit (e.g. a PC) wants to read the current values, it sends to the circuit-breaker a message containing:
- the numbers of the registers where the requested data shall be read (the measured quantities are associated to the register number; in the example, the registers from no. 30101 to 30104 are given, which contain the current values);
- the type of operation to be performed (e.g.: reading the values contained in the register).

The slave unit (in this specific case the circuit-breaker) answers by sending the requested values to the master.
Then, such values are shown to the operator in a format which can be understood through the user interfaces of the software and of the supervision application programs, which facilitate the presentation of the information and of the data from the controlled process.

[6] For further information about the structure of the Modbus logical map of the ABB trip units equipped with communication interface reference must be made to the following documents:
- *Modbus System Interface for protection relays PR122/P and PR123/P + communication module PR120/D-M, mounted on CB New Emax; Protection relays PR332/P and PR333/P + communication module PR330/D-M, mounted on CB Emax X1, Tmax T7 and Tmax T8 (document code: 1SDH000556R0001)*
- *Emax DC PR122DC-PR123DC + PR120/D-M Modbus System Interface (document code: 1SDH000841R0001)*
- *Emax VF PR122/VF + PR120/D-M Modbus System Interface (document code: 1SDH000922R0001)*
- *Instruction manual PR223EF Modbus System Interface (document code: 1SDH000566R0001)*
- *Instruction manual PR223DS Modbus System Interface (document code: 1SDH000658R0001)*
- *Instruction manual PR222DS/PD Modbus System Interface (document code: 1SDH000600R0001).*

- *The Modbus map (or memory map) is defined by the manufacturer, who decides what register is to be associated to the data read by the circuit-breaker, and moreover chooses which of the read parameters and which settings of the circuit-breaker can be transmitted via serial communication*

2.1.4 Compatibility between the protocol layers

In industrial communication, the different devices interchanging information must use the same protocols for all the layers involved.
For instance, as illustrated in the following chapters, ABB SACE circuit-breakers use protocol Modbus RTU over RS-485. However there are also industrial devices which use Modbus RTU over RS-232 or Profibus-DP over RS-485.

Some of the above mentioned combinations are shown in the table below highlighting which are the functioning and not-functioning ones.

PROTOCOL LAYERS	PROTOCOL OF THE DEVICE A	PROTOCOL OF THE DEVICE B	COMMUNICATION/DIALOGUE
Logical layer	Modbus RTU	Modbus RTU	**YES COMMUNICATION** Compatibility on all the layers of the protocol
Physical layer	RS-485	RS-485	
Logical layer	Modbus RTU	Modbus RTU	**YES COMMUNICATION** Compatibility on all the layers of the protocol
Physical layer	RS-232	RS-232	
Logical layer	Profibus-DP	Profibus-DP	**YES COMMUNICATION** Compatibility on all the layers of the protocol
Physical layer	RS-485	RS-485	
Logical layer	Profibus-DP	Modbus RTU	**NO COMMUNICATION** Incompatibility on the logical layer of the protocol
Physical layer	RS-485	RS-485	
Logical layer	Modbus RTU	Modbus RTU	**NO COMMUNICATION** Incompatibility on the physical layer of the protocol
Physical layer	RS-485	RS-232	
Logical layer	Profibus-DP	Modbus RTU	**NO COMMUNICATION** Incompatibility on all the layers of the protocol
Physical layer	RS-485	RS-232	

Note: With logical layer the combination of link layer + application layer is meant.

3 Supervision of electrical distribution plants

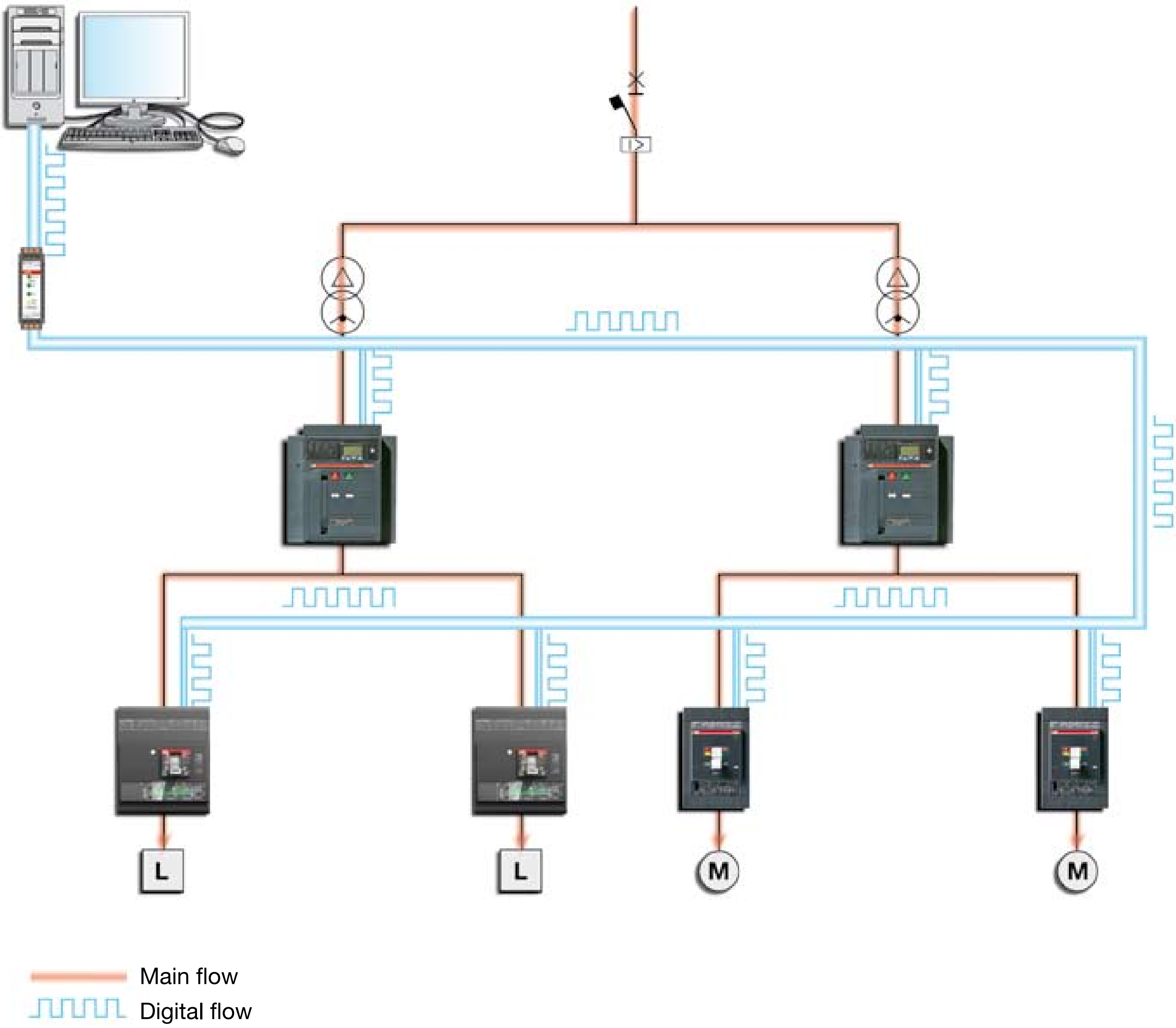
A low voltage electrical distribution plant can be considered as an industrial process oriented towards the distribution of electrical energy, and therefore, it also needs a supervision and control system to increase reliability and improve managing of the installation.

From a point of view aimed at the integration between traditional installation technology and control systems, with the aim of centrally and automatically managing, controlling, and monitoring civil and industrial plants, it is possible to consider the electrical installation as influenced by two flows:

- a main flow (energy flow) constituted by the power and the energy which, through the line conductors and the switching and protection apparatus, is delivered to the users and the loads of a plant;
- a digital flow constituted by all the information, the data and the commands useful for the control and management of the plant.

It is the supervision system which manages the digital flow passing over the communication network.

Figure 16: Representation of the main flow and of the digital flow



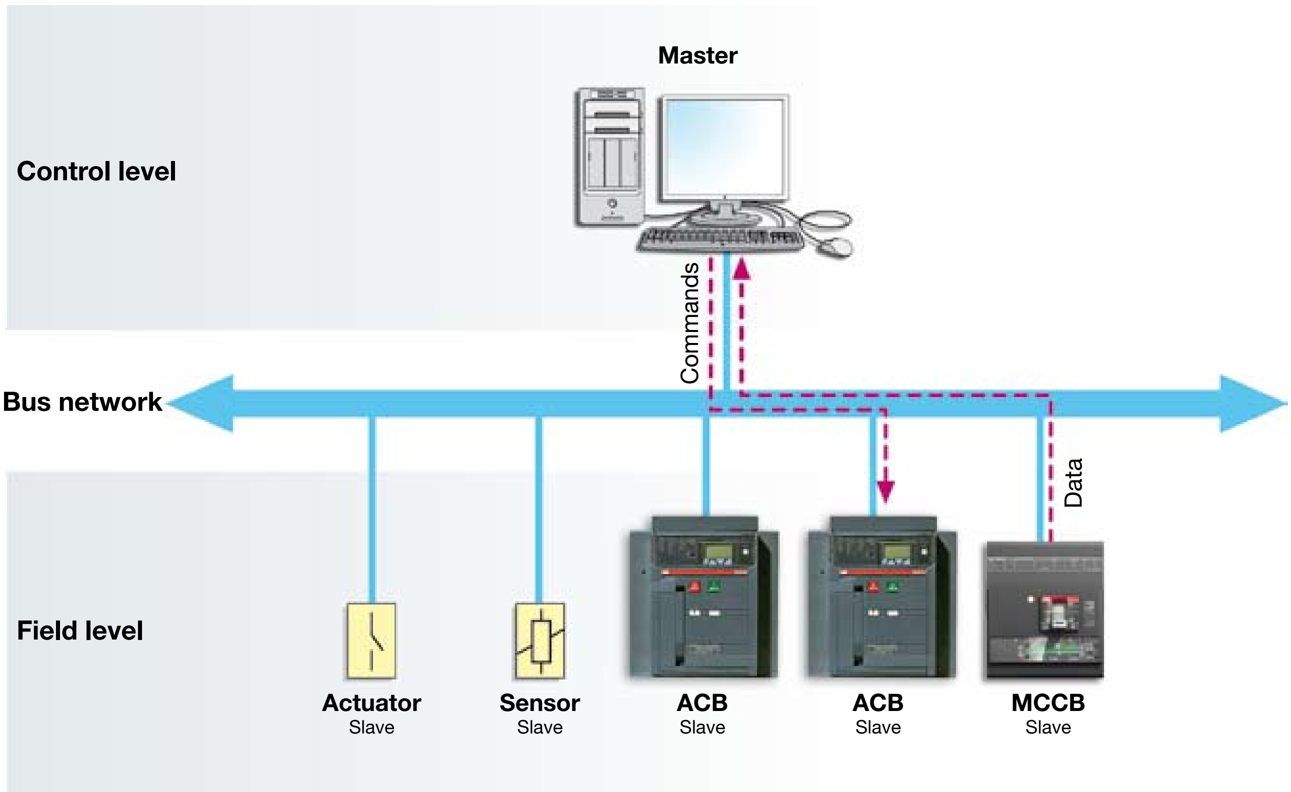
According to the extent and the complexity of the installations to be managed, it is possible to implement supervision systems with different architectures, from the simplest (two-layer architecture) to the most complex ones (multi-layer architecture).
In this document, for a simple treatment of the subject, the systems with two-level architecture suitable for the management of low and medium distribution plants are dealt with.
In this type of architecture two levels are distinguishable:

1) the control level: constituted by the supervision, control and data acquisition system (SCADA: Supervisory Control and Data Acquisition).
   In the most simple applications this level comprises a computer on which the software programmes for data acquisition, plant control or supervision are installed.
   It is at this level that the data transmitted by the sensors are acquired, displayed and processed and the commands are sent to the actuators.
   In this way, from a single work station, an operator can monitor the state of the whole plant and carry out the necessary operations to guarantee its efficiency and proper functioning.
   More in general, in the applications which combine the management of the electrical distribution plant and the process management, the control level is constituted by the control processor which supervises the automation system of the whole industrial process;

2) the field level: constituted by the field devices equipped with communication interfaces (sensors, actuators and protection circuit-breakers fitted out with suitable electronic trip units) which are installed in the electrical plant and interact directly with it connecting it with the control level.
   The main functions of the field level are:
   1) transmitting the plant data (e.g. currents, voltages, energies, state of the circuit-breakers, etc.) to the control level
   2) actuating the commands (e.g. opening/closing of the circuit-breakers) received by the control level.

The two levels communicate through a bus network.
The information (e.g. the measured values) transmitted from the field level to the control level and the commands, which travel in the opposite direction, constitute the informative flow which runs on the bus.

Figure 17: Supervision system with two-level architecture



3.1 Supervision with ABB SACE circuit-breakers

In the field of energy distribution, communication and dialogue between protection devices are made possible by the microprocessor-based trip units equipped with the Modbus communication interface.
The use of these trip-units allows ABB SACE circuit-breakers to:

- exchange data with other electronic devices through a communication bus and to interact with the supervision systems for the computer-based management of low voltage electrical installations
- integrate the management of the electrical distribution plant with the automation systems of a whole factory or industrial process; for instance, integrate the information (currents, voltages and powers) coming from the circuit-breakers which protect the motors, the auxiliary circuits and the supply line of the electrical furnaces of a steelworks with the information and the data relevant to the physical quantities (e.g. pressure and temperature) involved in the management of the whole process.
  In this way, the circuit-breaker equipped with Modbus interface, besides carrying out the classic function of protecting the plant against overcurrents and deliver energy to the loads, also takes the function of field device of the supervision system functioning both as transmitter[7] as well as actuator.
  The use as a transmitter makes it possible to keep under control the electrical energy consumption and to improve the management of the electrical distribution plant.

The energy consumptions of an electrical plant which supplies a definite manufacturing process can be controlled, stored and analyzed with purpose of:

- reducing the power consumption in real time by disconnecting the non-priority loads if the effective drawn power exceeds the maximum contractual power so as to avoid the payment of penalties to the power supply authority;
- identifying the type of electrical power supply contract which is most suitable and compatible with the real requirements of the plant through a continuous control and an analysis of the energy withdrawal. In this way, it is possible to avoid signing a contract which is not aligned with the variations of the energy withdrawals during the year and find yourself, for instance, to pay a fine for the periods when the consumed power exceeds the maximum power fixed by contract;
- identifying and allocating the energy costs associated to the industrial process under control.

Besides, thanks to the information included in the circuit-breakers, it is possible, for example:

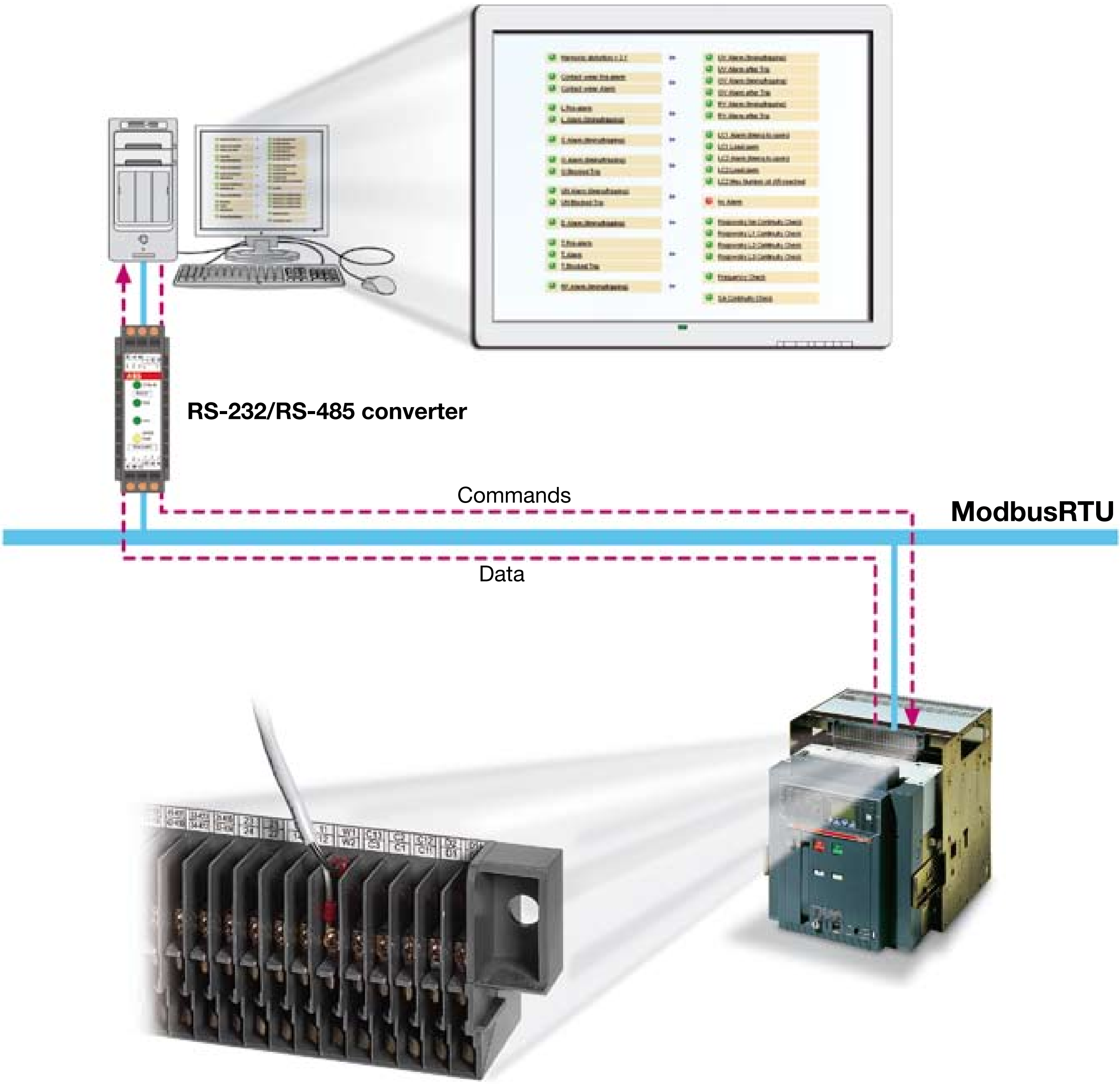
- to keep under control the electrical energy distribution system and guarantee the optimum operation of the industrial process it supplies;
- to verify that the main electrical quantities are in the range of the relevant rated values and that the plant works properly. In this way it is possible to control that the electrical supply has a good quality level;
- to control the alarm signals of the circuit-breakers in order to prevent situations of anomalous operation, faults and the consequent tripping of the protections, with the aim of reducing to a minimum inefficiencies and down times;
- to have dedicated information about the fault causes in a definite section of the electrical plants. For instance, such causes can be determined by storing and analyzing the phase currents (e.g.: trip due to a 12356 A short-circuit on the phase L2 on 04.28.2006 at 12:25). With this type of information a statistical survey of the occurred abnormal conditions is possible, thus allowing a statistical study on the fault causes);
- to know the diagnostics data of the protection devices (e.g. percentage of contact wear) in order to schedule preventive maintenance compatible with the working cycle of the supplied process, so as to limit to a minimum the downtimes and guarantee service continuity for the installation.

Moreover, the use of circuit-breakers as transmitters of the supervision system makes it possible measuring of the main electrical quantities of the plant (currents, voltages, powers) without using dedicated instruments.

The above involves cost savings in terms of purchase costs of equipment and moreover it allows saving space inside the distribution switchboards since it is not necessary to install inside it the sensors to be interfaced with the control system.

[7] For transmitter a sensor is meant which transmits the measured data through a communication system. In this document, the two terms "sensor" and "transmitter", are used as synonym.

Figure 18: The circuit-breaker as sensor and actuator of a supervision system



4 ABB solution for bus communication

This chapter describes:
- the electronic trip units, the accessories and the products which enable ABB SACE circuit-breakers to be integrated into the field buses Modbus RTU, Profibus DP and DeviceNet for the supervision and the remote control of LV electrical distribution plants;
- the front panel interface HMI030;
- the rules for the arrangement of the Modbus RS-485 network;
- ABB digital measuring instruments with communication function.

4.1 Emax air circuit-breakers

PR122/P - PR123/P electronic trip units for alternating current applications
Modbus communication: supervision and remote control
Emax air circuit-breakers provided with the electronic trip unit type PR122/P or PR123/P to be interfaced with Modbus networks need the suitable communication module PR120/D-M (for the characteristics of the module see Annex C), in order to:

- transmit the alarm signals of the protections, the information about the circuit-breaker (e.g.: state and position) and the measures made available by the trip unit to a remote control system thus implementing supervision;
- receive from a remote supervision system the commands (e.g.: opening and closing of the circuit-breaker) or the settings of the protection functions, thus implementing remote control.

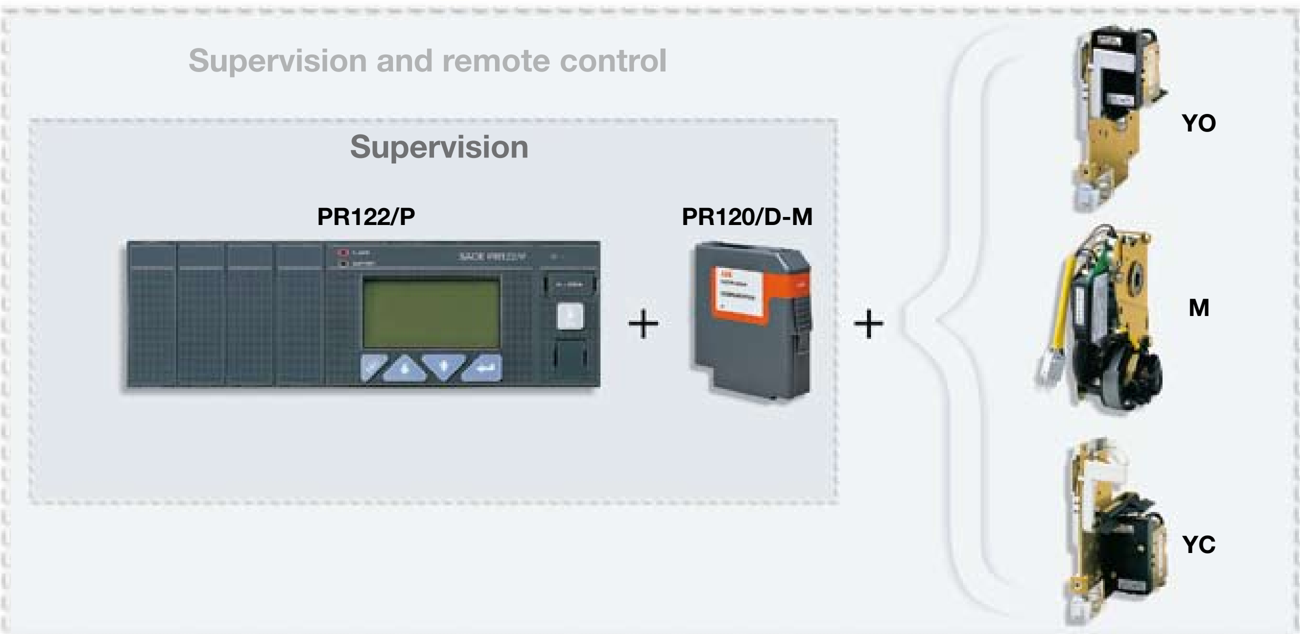
To perform the remote control, i.e. the mechanical implementation of the remote opening and closing commands, the circuit-breakers of Emax series together with PR120/D-M communication module must be equipped also with the following accessories:
- shunt opening release (YO)
- shunt closing release (YC)
- geared motor for the automatic charging of the closing springs (M).

As regards bus communication, remind that the auxiliary supply voltage Vaux is necessary for the trip units PR122/P and PR123/P (for its technical characteristics see Annex B).

Measures
The measures made available depend on the typology of the trip unit used and on the presence, or not, of the measuring module PR120/V.
The voltage measuring module PR120/V (see Annex D), which must be required for PR122/P whereas it is fitted out by default on PR123/P, allows the trip units to make available, in addition to the current measure, also the main electrical quantities of the plant, such as e.g the power (see Annex A). The measured values can be sent, by means of PR120/D-M, to the remote supervision system.
For measures, data, alarms and remote control operations please refer to Table A.1 in Annex A.
All the commands from remote control (through the bus) can be disabled by setting the trip unit to local mode.

PR122/P electronic trip unit

- PR122/P + PR120/D-M communication module + remote control accessories (YO, YC, M)



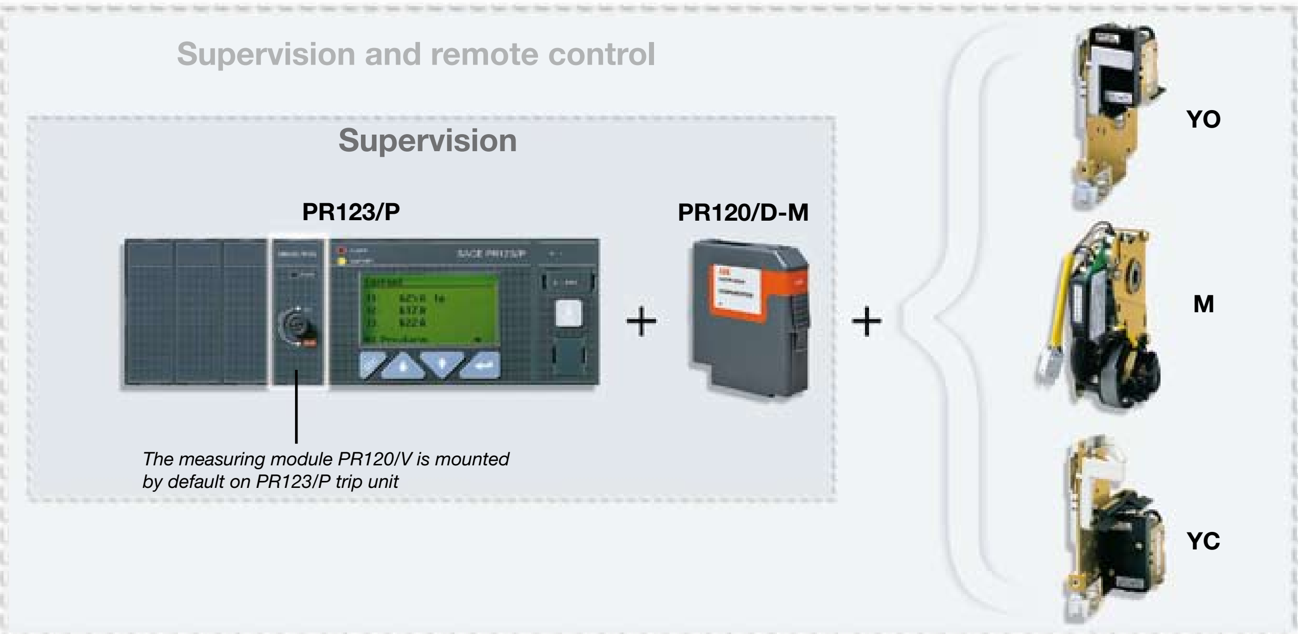
Note: together with PR120/D-M module, also the contact signaling spring charged and the contact signaling CB in racked-in/out position are supplied.

- PR122/P + PR120/D-M communication module + remote control accessories (YO, YC, M)

Note: together with PR120/D-M module, also the contact signaling spring charged and the contact signaling CB in racked-in/out position are supplied.

PR123/P electronic trip unit

- PR123/P + PR 120/D-M communication module + remote control accessories (YO, YC, M)



Note: together with PR120/D-M module, also the contact signaling spring charged and the contact signaling CB in racked-in/out position are supplied

PR122/DC and PR123/DC electronic trip units for direct current applications

LV circuit-breakers type E2, E3, E4 and E6 of SACE series Emax DC for direct current applications, equipped with electronic trip unit type PR122/DC or PR123/DC can be integrated into the communication systems with the Modbus RTU field bus for the supervision and control of direct current installations with voltages up to 1000Vd.c.
PR120/D-M communication module must be used for the connection to the Modbus network (see Annex C).
PR120/V measuring module is installed by default inside PR122/DC and PR123/DC trip units.
To implement, from a remote supervision system, opening and closing commands on the circuit-breakers series SACE Emax DC the following accessories are necessary (the same ones used for the remote control of standard Emax circuit-breakers for alternating current applications):
- shunt opening release (YO)
- shunt closing release (YC)
- geared motor for the automatic charging of the closing springs (M).

As regards bus communication, please note that the trip units PR122/DC and PR123/DC must be supplied with an auxiliary supply voltage of 24 V DC (for its technical characteristics see Annex B).

The measures, data, information and control operations from remote are summarized in Table A.1A of Annex A.
All the commands from remote control (via bus) can be blocked by setting the trip unit to local mode.

As regards the configuration of use of PR122/DC and PR123/DC trip units with the accessories for the Modbus communication, reference must be made to the configuration of use of PR123/P trip unit for alternating current shown on page 15 of this document.

NOTE: For a deeper analysis on direct current plants please consult Technical Application Paper No. 5: “ABB circuit-breakers for direct current applications”.

PR122/VF electronic trip unit for variable frequency applications

Low voltage circuit-breakers type E2/VF and E3/VF series SACE Emax VF, for variable frequency applications (in particular at low frequency from 1 to 60 Hz), equipped with electronic trip unit PR122/VF, can be integrated into the communication systems with the Modbus RTU fieldbus for the supervision and control of variable frequency installations (e.g. wind power turbines) with rated operating voltage up to 1000V a.c. and current up to 2500A.
For the connection to the Modbus network the communication module PR120/D-M must be used (see Annex C).

To implement, from a remote supervision system, opening and closing commands on the circuit-breakers series SACE Emax VF the following accessories are necessary (the same ones used for the remote control of standard Emax circuit-breakers for alternating current applications):
- shunt opening release (YO)
- shunt closing release (YC)
- geared motor for the automatic charging of the closing springs (M).

As regards bus communication, please note that the trip units PR122/VF must be supplied with an auxiliary supply voltage of 24 V DC (for its technical characteristics see Annex B).

The measures, data, information and control operations from remote are summarized in Table A.1B of Annex A.
All the commands from remote control (via bus) can be blocked by setting the trip unit to local mode.

As regards the configuration of use of the trip unit PR122/VF with the accessories for the Modbus communication, reference must be made to the configuration of use of PR122/P trip unit for alternating current shown on page 14 of this document.

NOTE: For a deeper analysis on variable frequency applications in wind power systems please consult Technical Application Paper No. 13: “Wind power plants”.

NOTE: For more detailed information about the dialogue functions and the characteristics of the products described in this clause reference must be made to the relevant catalogues and product technical manuals.

For further information on the structure of the Modbus map of the ABB trip units provided with communication interfaces, reference must be made to the following documents:
- Modbus system Interface for Protection relays PR122/P and PR123/P + communication module PR120/D-M, mounted on CB New Emax; Protection relays PR332/P and PR333/P + communication module PR330/D-M, mounted on CB Emax X1, Tmax T7 and Tmax T8 (document code: 1SDH000556R0001)
- Emax DC PR122DC-PR123DC + PR120/D-M Modbus System Interface (document code: 1SDH000841R0001)
- Emax VF PR122/VF + PR120/D-M Modbus System Interface (document code: 1SDH000922R0001).

4.2 Emax X1 air circuit-breakers and Tmax T7 moulded-case circuit-breakers

Modbus communication: supervision and remote control
To be interfaced with Modbus networks Emax X1 air circuit-breakers equipped with the electronic trip unit type PR332/P or PR333/P and Tmax T7 moulded-case circuit-breakers provided with PR332/P electronic trip unit, need the suitable communication module PR330/D-M (for the characteristics of the module see Annex C), in order to:

- transmit the alarm signals of the protections, the information about the circuit-breaker (e.g.: state and position) and the measures made available by the trip unit to a remote control system thus implementing supervision.

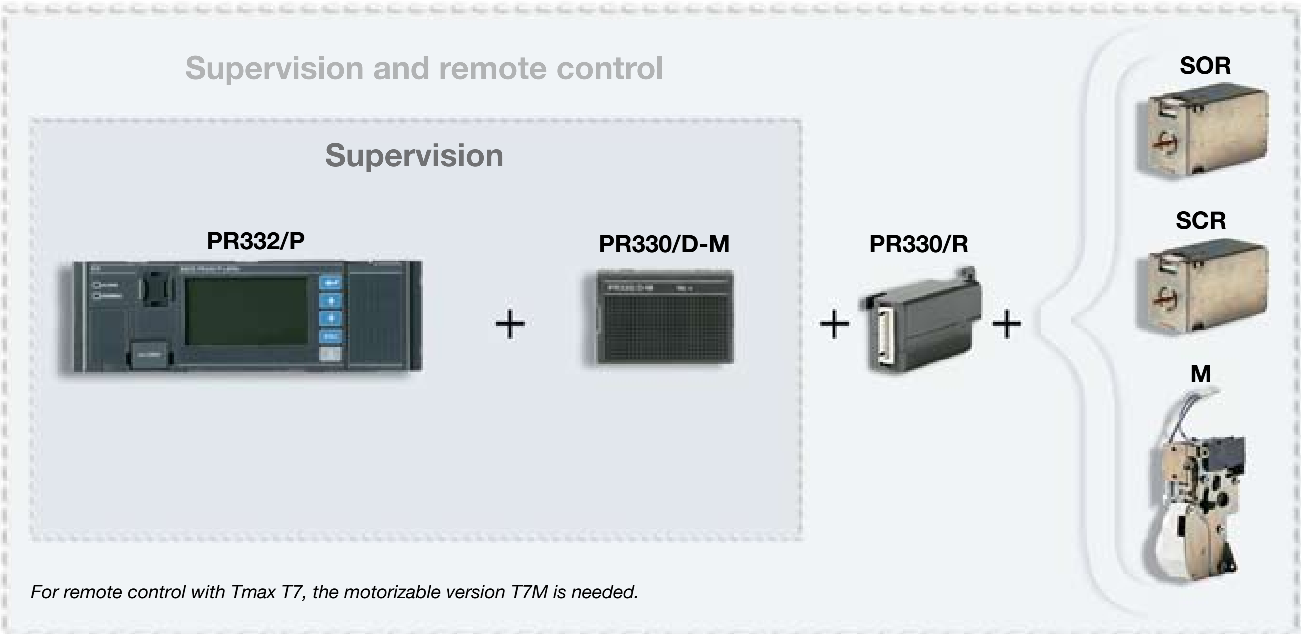
- receive from a remote supervision system the settings of the protection functions or the commands (e.g.: opening and closing of the circuit-breaker), thus implementing remote control.
  The circuit-breakers Emax X1 and Tmax T7 in motorizable version T7M can be controlled from remote.
  Tmax T7 in not-motorizable version cannot be controlled from remote.
  To perform the remote control, i.e. the mechanical implementation of the remote opening and closing commands, the circuit-breakers type Emax X1 and Tmax T7M, with PR330/D-M communication module, must be equipped also with the following accessories:
  - PR330/R actuation module (see Annex C)
  - shunt opening release (SOR)
  - shunt closing release (SCR)
  - geared motor for the automatic charging of the closing springs (M).

As regards bus communication, remind that it is necessary to supply the trip units PR332/P and PR333/P with the auxiliary voltage Vaux (for its characteristics see Annex B).

Measures
The measures made available depend on the typology of trip unit used and on the presence of the measuring module PR330/V.
The voltage measuring module PR330/V (see Annex D), which must be provided for PR332/P, whereas it is fitted out by default on PR333/P, allows the trip units to make available, in addition to the current measures, also the main electrical quantities of the plant, such as for example the power (see Annex A).
The measured values can be sent, by means of PR330/D-M, to the remote supervision system.
For measures, data, alarms and remote control operations please refer to Table A.1 in Annex A.
All the commands from remote control (through the bus) can be disabled by setting the trip unit to local mode.

PR332/P electronic trip unit for Emax X1 and Tmax T7

- PR332/P + PR330/D-M communication module + accessories for the remote control (PR330/R, SOR, SCR, M)



Note: together with PR330/D-M module, also the contact signaling spring charged and the contact signaling CB in racked-in/out position are supplied.

- PR332/P + PR330/D-M communication module + PR330/V measuring module + accessories for the remote control (PR330/R, SOR, SCR, M).

Note: together with PR330/D-M module, also the contact signaling spring charged and the contact signaling CB in racked-in/out position are supplied.

PR333/P electronic trip unit for Emax X1

- PR333/P + PR330/D-M communication module + accessories for the remote control (PR330/R, SOR, SCR, M)

Note: together with PR330/D-M module, also the contact signaling spring charged and the contact signaling CB in racked-in/out position are supplied.

NOTE: For more detailed information about the dialogue functions and the characteristics of the products described in this clause reference must be made to the relevant catalogues and product technical manuals.
For further information on the structure of the Modbus map of the ABB trip units provided with communication interfaces, reference must be made to the following documents:
- Modbus system Interface for Protection relays PR122/P and PR123/P + communication module PR120/D-M, mounted on CB New Emax; Protection relays PR332/P and PR333/P + communication module PR330/D-M, mounted on CB Emax X1, Tmax T7 and Tmax T8 (document code: 1SDH000556R0001)

4.3 Moulded-case circuit-breakers Tmax T4-T5-T6

Modbus communication: supervision and remote control.
The trip units type PR222DS/PD, PR223EF and PR223DS for the circuit-breakers type Tmax T4, T5 and T6 can be interfaced to Modbus networks through the suitable X3 rear connector (see Annex C).
Communication and dialogue are implemented in order to:

- transmit the alarm signals of the protections, the information about the circuit-breaker (e.g.: state and position) and the measures made available by the trip unit to a remote supervision system, thus implementing supervision.
  To make available for the remote supervision system the information about the circuit-breaker state (open, closed, tripped) the circuit-breakers Tmax T4, T5 and T6 must be equipped with the AUX-E auxiliary contacts in electronic version (see Annex E).

- receive from a remote supervision system the commands (e.g.: opening and closing of the circuit-breaker) or the settings of the protection functions thus implementing remote control.
  To perform the remote control, i.e. the mechanical implementation of the remote opening and closing commands, Tmax moulded-case circuit-breakers type T4, T5 and T6 must be equipped with the motor operator with electronic interface MOE-E (Annex E) and the AUX-E auxiliary contacts in electronic version (Annex E).

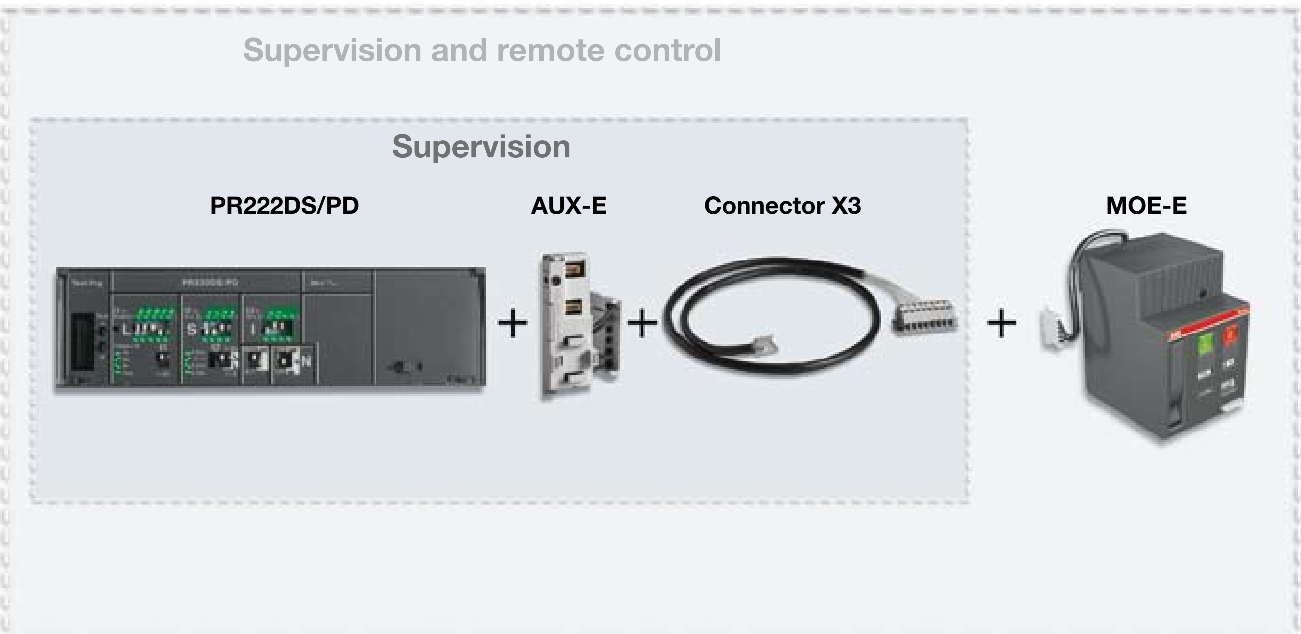
As regards bus communication, remember that the auxiliary supply voltage Vaux is necessary for the trip units PR222DS/PD, PR223EF and PR223DS (for its characteristics see Annex B).

Measures
The trip units type PR222DS/PD, PR223EF and PR223DS give the measure of the currents in the three phases, in the neutral and to earth.
Thanks to the voltage measuring module VM210 and X4 rear connector (see Annex D), the trip units type PR223EF and PR223DS can measure, in addition to the currents, also the main electrical quantities of the plant (see Annex A). The measured values can be sent to the remote supervision system by the trip unit, through the terminals 1 and 2 of X3 connector.

For measures, data, alarms and remote control operations please refer to Table A.2 in Annex A.
All the commands from remote control (through the bus) can be disabled by setting the trip unit to local mode.

PR222DS/PD electronic trip unit

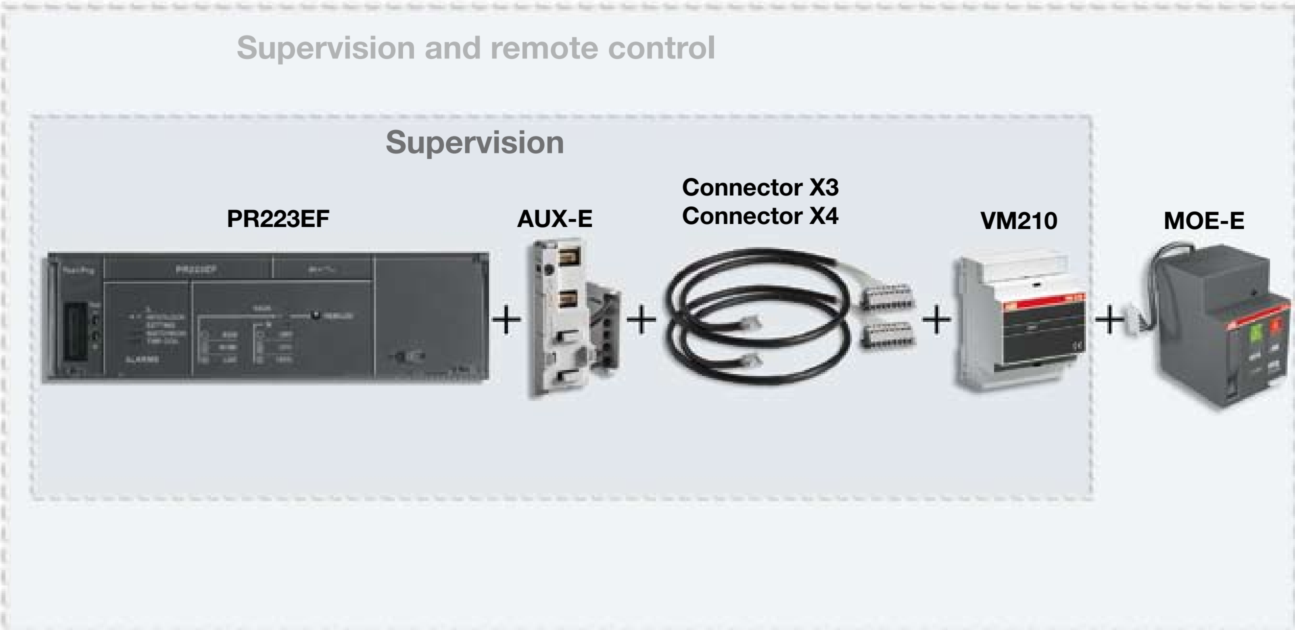
- PR222DS/PD + AUX-E auxiliary contacts in electronic version + X3 connector + MOE-E motor operator with electronic interface



PR223EF electronic trip unit

- PR223EF + AUX-E auxiliary contacts in electronic version + X3 connector + MOE-E motor operator with electronic interface

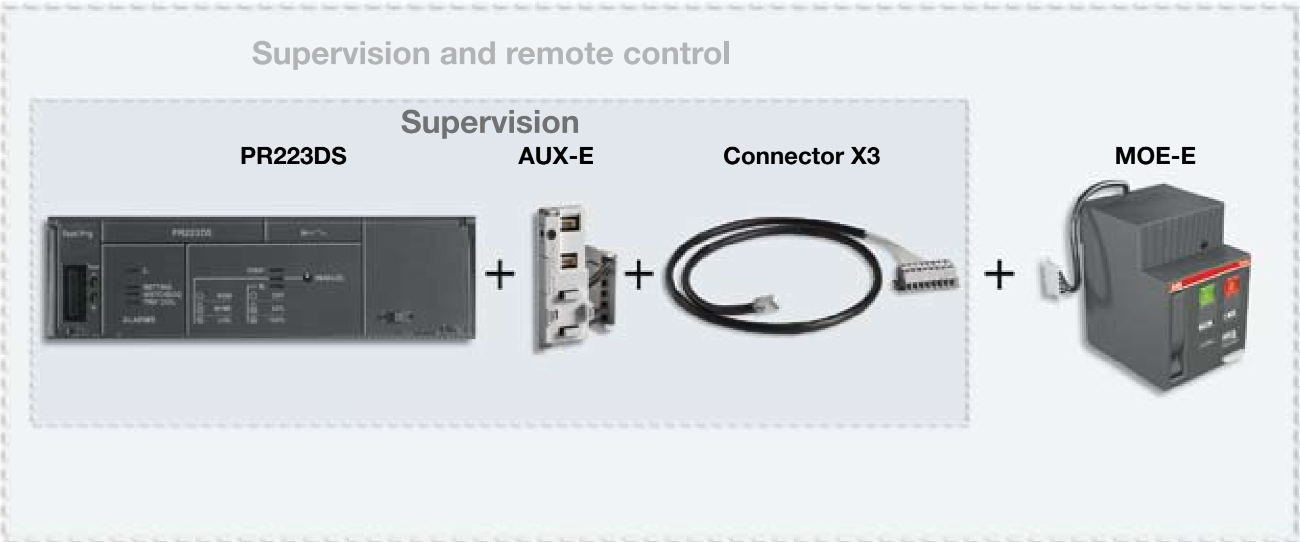
- PR223EF + AUX-E auxiliary contacts in electronic version + X3 connector + X4 connector + VM210 measuring module + MOE-E motor operator with electronic interface



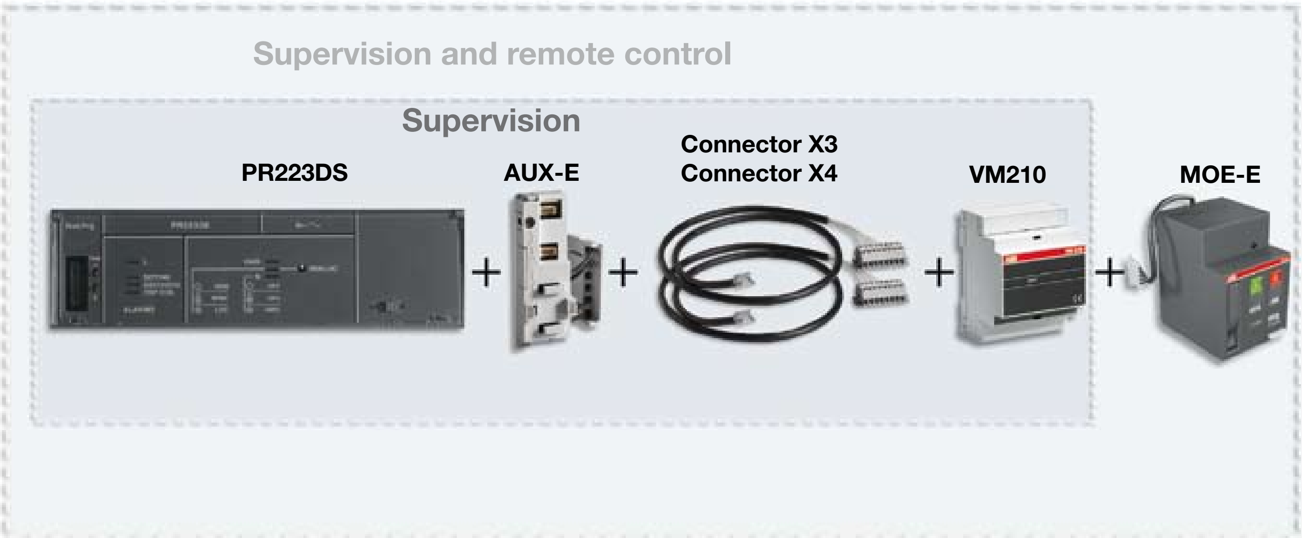
4 ABB solution for bus communication

PR223DS electronic trip unit

- PR223DS + AUX-E auxiliary contacts in electronic version + X3 connector + MOE-E motor operator with electronic interface



- PR223DS + AUX-E auxiliary contacts in electronic version + X3 connector + X4 connector + VM210 measuring module + MOE-E motor operator with electronic interface



NOTE: For more detailed information about the dialogue functions and the characteristics of the products described in this clause reference must be made to the relevant catalogues and product technical manuals.

For further information on the structure of the Modbus map of the ABB trip units provided with communication interfaces, reference must be made to the following documents:
- Instruction manual PR223EF Modbus System Interface (document code: 1SDH000566R0001)
- Instruction manual PR223DS Modbus System Interface (document code: 1SDH000658R0001)
- Instruction manual PR222DS/PD Modbus System Interface (document code: 1SDH000600R0001).

4 ABB solution for bus communication

4.4 Moulded-case circuit-breakers SACE Tmax XT2-XT4

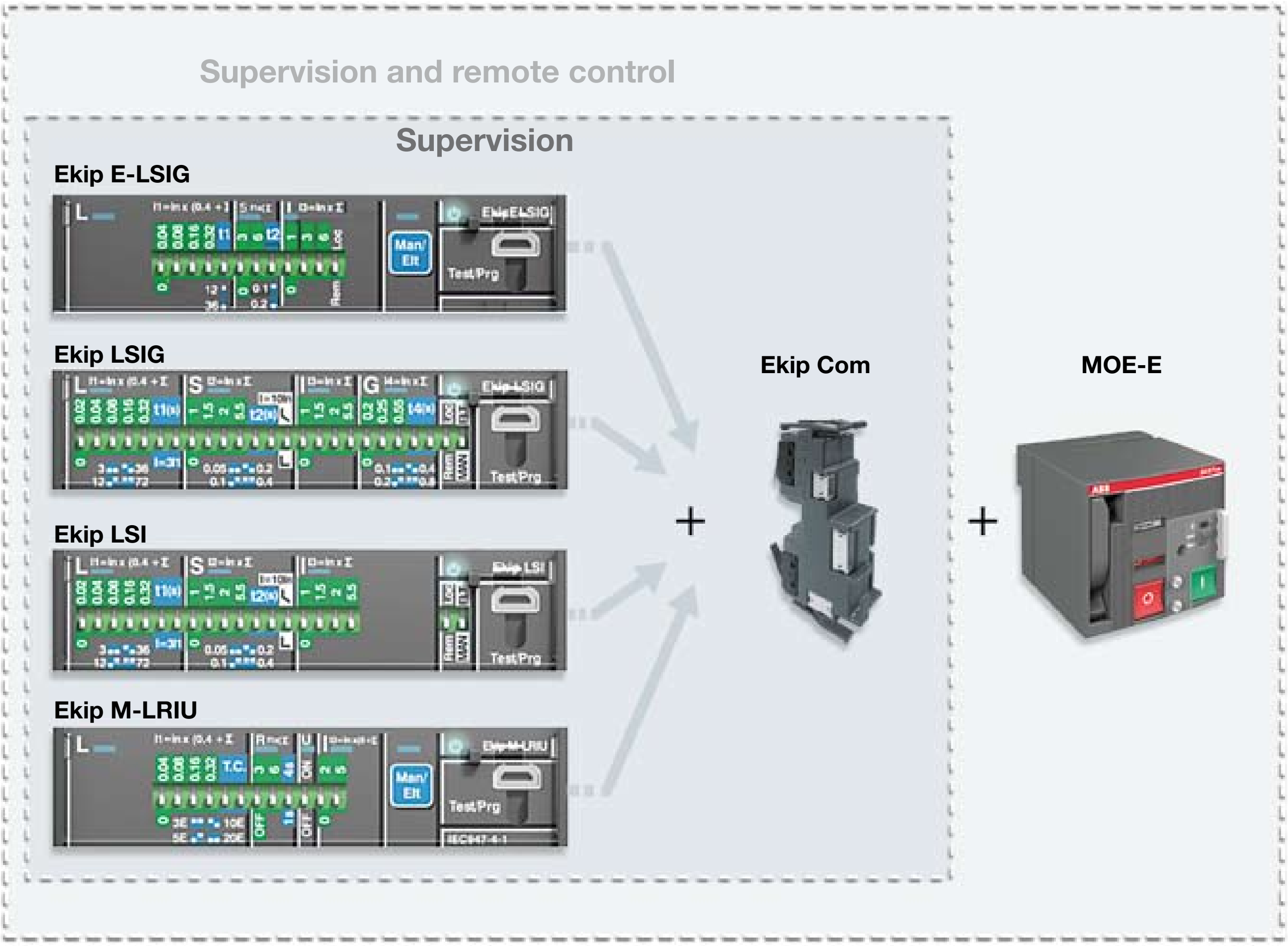
Modbus communication: supervision and remote control
The electronic trip units type Ekip LSI, Ekip LSIG, Ekip M-LRIU and Ekip E-LSIG (the last one for SACE Tmax XT4 circuit-breakers only) can be integrated into the communication systems with Modbus RTU fieldbus, for the supervision and remote control of low voltage electrical plants. The connection to the Modbus network is carried out through Ekip Com module (for information see Annex C), which is the communication interface necessary to connect the above mentioned electronic trip units to the fieldbus and make them dialogue with the supervision systems.
Thus it is possible to:
- acquire from remote all the measures, the information, the alarms available in the trip unit and the circuit-breaker state for the supervision of the electrical plant (e.g.: control the energy consumption and monitor the quality of the electrical network);
- send from remote opening/closing and reset commands (if the circuit-breaker is equipped with MOE-E motor operator see Annex F);
- set from remote the configuration, programming and protection parameters (current thresholds and trip times of the protections, curves of the protection functions) of the trip unit.

SACE Tmax XT2-XT4 moulded-case circuit-breakers can be used in the communication systems for a complete and total supervision of the electrical plant starting from load currents of 4 A; for example this is possible with a moulded-case circuit-breaker type SACE Tmax XT2 equipped with Ekip LSI electronic trip unit In = 10 A and protection L set at 0.4 In.
For the communication and dialogue functions, the Ekip Com module and the electronic trip unit must be supplied with 24 V DC auxiliary voltage (Vaux) (for the technical characteristics see Annex B).
To accomplish from remote the opening/closing and reset commands, the moulded-case circuit-breakers type SACE Tmax XT2 and XT4 must be equipped with MOE-E motor operator with electronic interface (see Annex F).

Measures
In addition to the supervision functions described above, the trip units with communication interface allow the electrical quantities of the plant to be monitored by sending to the supervision and control system the measures they make available.
In particular, the electronic trip units Ekip LSI, Ekip LSIG and Ekip M-LRIU are able to measure the current values (currents in the three phases, in the neutral and to earth).
Ekip E-LSIG electronic trip units for SACE Tmax XT4 circuit-breakers put at disposal, in addition to the current values, also the main electrical parameters of the plant, such as: voltages (line-to-line and line-to-neutral), power, energy (to optimize consumption as well as their allocation, frequency and harmonic distortion rate (THD and spectrum) to control the quality of the energy.
All the electrical quantities are measured by the Ekip-E LSIG without any help from external measuring modules.
The measured electrical quantities are stored in the trip unit, with the possibility of being transmitted to the control system for the supervision of the electrical plant.
The main data, alarms and measures put to disposal by each trip unit are summarized in Table A.3 of Annex A.
All the commands from remote control (via bus) can be blocked by setting the trip unit to local mode.

Electronic trip units Ekip E-LSIG, Ekip LSIG, Ekip LSI and Ekip M-LRIU

- Ekip E-LSIG/LSIG/LSI/M-LRIU + Ekip Com communication module + MOE-E motor operator



Through Ekip Com communication module it is possible to integrate the following equipment into the supervision systems:
- SACE Tmax XT2 and XT4 circuit-breakers, with electronic trip units Ekip LS/I, Ekip I, Ekip M-LIU, Ekip G-LS/I and Ekip N-LS/I without Modbus communication, and the circuit-breakers with thermomagnetic trip units TMA, TMD, TMG (which can be used also for applications in continuous current);

- SACE Tmax XT4D switch-disconnectors
  With this configuration, it is possible to:

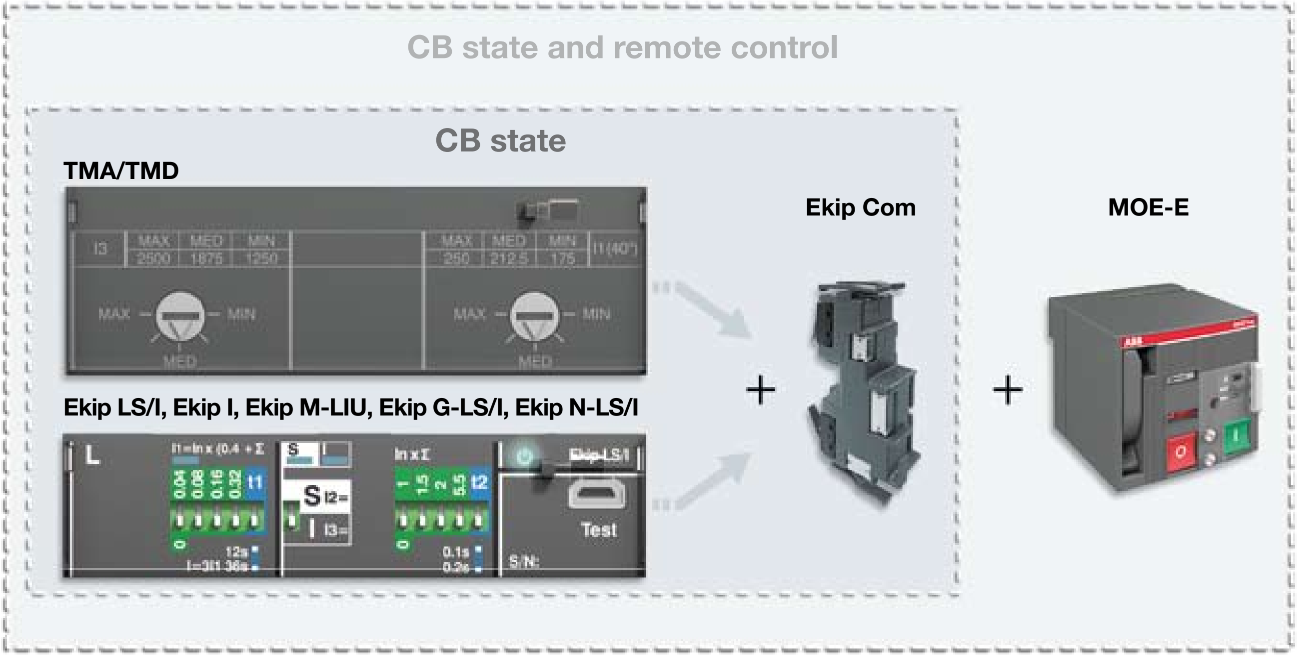
- acquire from remote the circuit-breaker state (open/closed, tripped) or the switch-disconnector state (open/closed);

- send from remote opening/closing commands to the circuit-breaker/switch-disconnector and reset commands to the circuit-breaker only, if the circuit-breaker/switch-disconnector are equipped with MOE-E - motor operator with electronic interface (see Annex F).

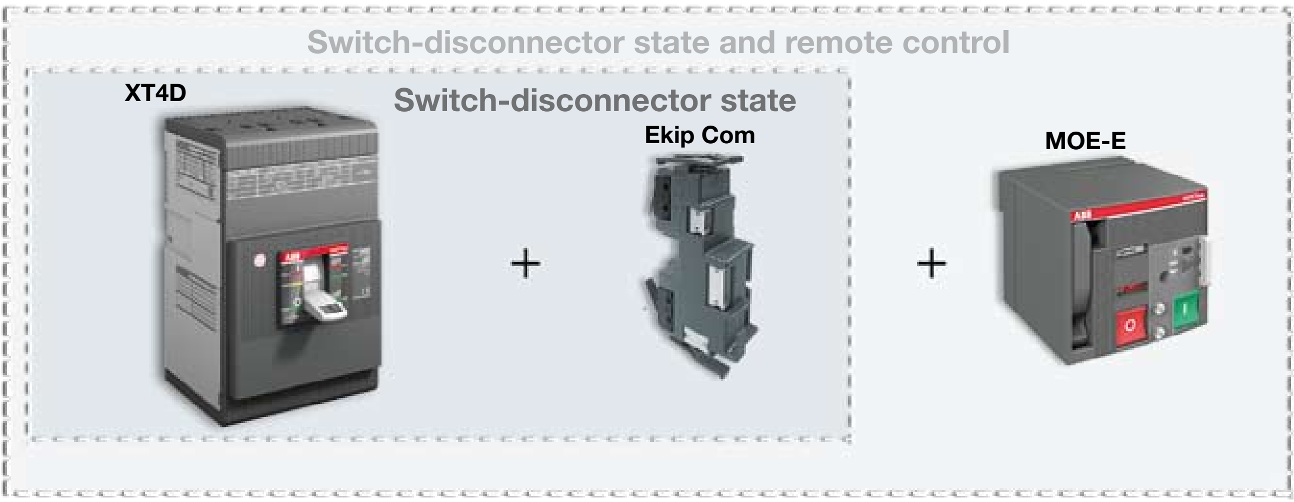
Also in this configuration, the module Ekip Com must be supplied with 24 V DC auxiliary supply (Vaux) - for the technical characteristics see Annex B.

Circuit-breakers with TMA/TMD thermomagnetic trip units, Ekip electronic trip units without Modbus communication and SACE Tmax XT4D switch-disconnectors

- TMA/TMD-Ekip without Modbus communication + Ekip Com communication module + MOE-E motor operator



- SACE Tmax XT4D switch-disconnector + Ekip Com communication module + MOE-E motor operator



NOTE: For more detailed information about the dialogue functions and the characteristics of the products described in this clause reference must be made to the relevant catalogues and product technical manuals.

4.5 SD030DX solution for the circuit-breakers without Modbus RTU interface

SD030DX are electronic devices which allow the interface of:

- air and moulded-case circuit-breakers equipped with thermomagnetic or basic electronic trip unit
- air or moulded-case switch-disconnectors

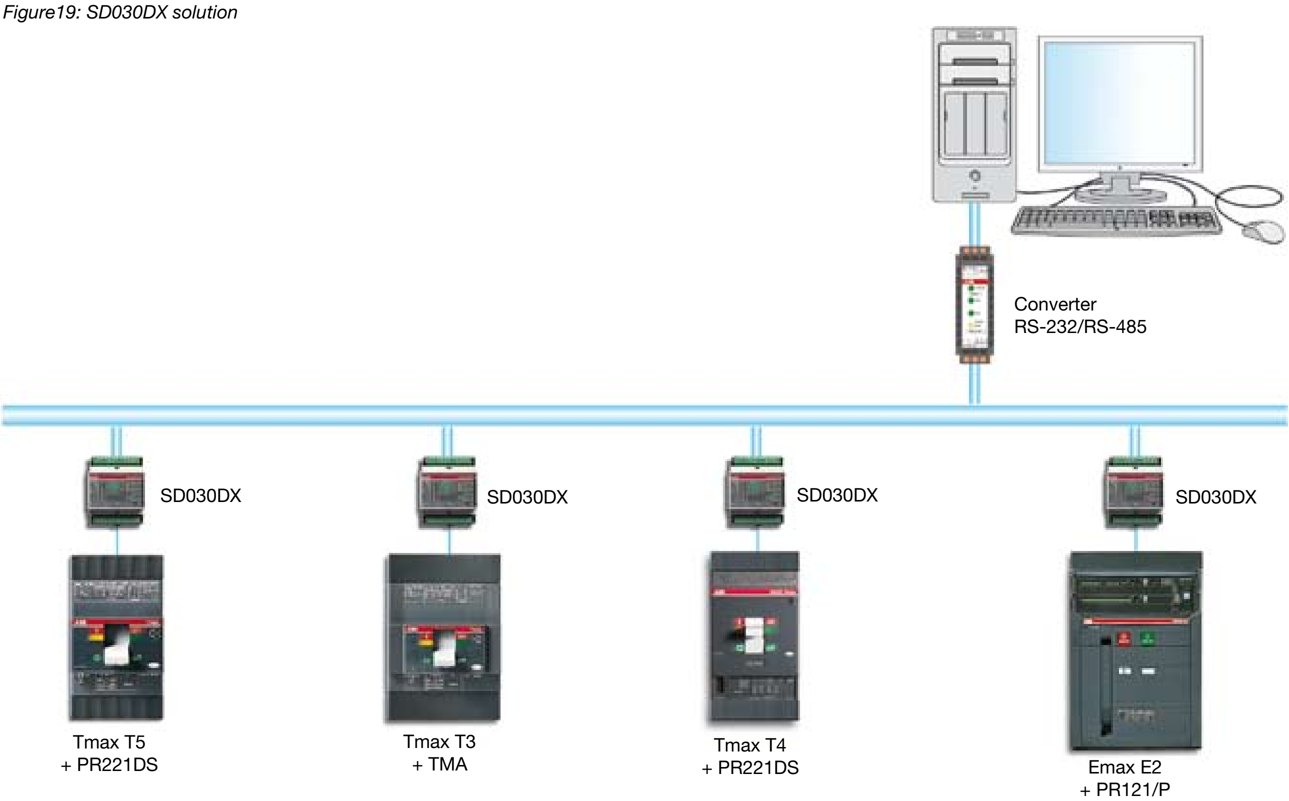
to a Modbus network.
The circuit-breakers and the switch-disconnectors connected in this way appear on the Modbus network as slave units and can communicate with whatever masters (PC, PLC, SCADA).
This makes it possible for the supervision systems to manage also these apparatus.
In particular, the supervision system can:
1) read the circuit-breaker state: open, closed, tripped, racked-in/out, charged/discharged springs
2) command opening, closing and reset of the devices.

Reading of the state of the apparatus is carried out through the auxiliary contacts (which therefore must be mounted on the circuit-breaker).
As regards commands instead, the circuit-breaker/switch-disconnector must be fitted out with suitable accessories.

The main characteristics of SD030DX are shown in the following table:

Type of device	Features	Description
SD030 DX	- 3 digital outputs	- Open, Closed, Reset
	- 5 digital inputs	- Acquisition of CB state

Figure19: SD030DX solution



Reading of the circuit-breaker state

To read the circuit breaker state, up to 5 auxiliary contacts can be used, connected respectively to the five digital inputs (DI1, DI2, DI3, DI4 and DI5) of SD030DX.

The following table shows:

- the circuit-breakers and the switch-disconnectors which can be managed through SD030DX
- the information associated to each digital input (with the corresponding auxiliary contact) for the different type of circuit-breaker.

Circuit-breaker type	Associated information					
	Springs	Protection	CB state			Mode
	Discharged=0 Charged=1	Normal=0 Tripped=1	Racked-out=0 Racked-in=1	Open=0 Closed=1	Normal=0 Tripped=1	Remote=0 Local=1
T1-T2-T3 with 5-wire solenoid operating mechanism	-	DI2 + contact for the electrical signaling of tripped protection (S51)	DI3 + contact for the electrical signaling of circuit-breaker in racked-in position (S75I/1)	DI4 + CB auxiliary contacts (Q/1)	DI1 + contact for the electrical signaling of circuit-breaker tripped (SY)	-
T4-T5-T6	-	DI2 + contact for the electrical signaling of tripped protection (S51)	DI3 + contact for the electrical signaling of circuit-breaker in racked-in position (S75I/1)	DI4 + CB auxiliary contacts (Q/1)	DI1 + contact for the electrical signaling of circuit-breaker tripped (SY)	DI5 + switching contact for electrical signaling of local/ remote selector state (S3/1)
T7, X1 E1÷ E6	DI1 + limit contact for spring-charging motor (S33M/1)	DI2 + contact for the electrical signaling of circuit-breaker open due to the tripping of the overcurrent trip unit (S51)	DI3 + contact for the electrical signaling of circuit-breaker in racked-in position (S75I/1)	DI4 + CB auxiliary contacts (Q/1)	-	DI5 + switch for setting remote/local control (S43)
Switch-disconnector type						
T1D-T3D with 5-wire solenoid operating mechanism	-	-	DI3 + contact for the electrical signaling of circuit-breaker in racked-in position (S75I/1)	DI4 + CB auxiliary contacts (Q/1)	-	-
T4D-T5D-T6D	-	-	DI3 + contact for the electrical signaling of circuit-breaker in racked-in position (S75I/1)	DI4 + CB auxiliary contacts (Q/1)	-	DI5 + switching contact for electrical signaling of local/ remote selector state (S3/1)
T7D, X1B/MS E1/MS ÷ E6/MS	DI1 + limit contact for spring-charging motor (S33M/1)	-	DI3 + contact for the electrical signaling of circuit-breaker in racked-in position (S75I/1)	DI4 + CB auxiliary contacts (Q/1)	-	DI5 + switch for setting remote/local control (S43)

Remote control

The SD030DX units carry out the commands (opening, closing and reset) sent by the supervision system to the circuit-breaker/switch-disconnector.

The following table shows:

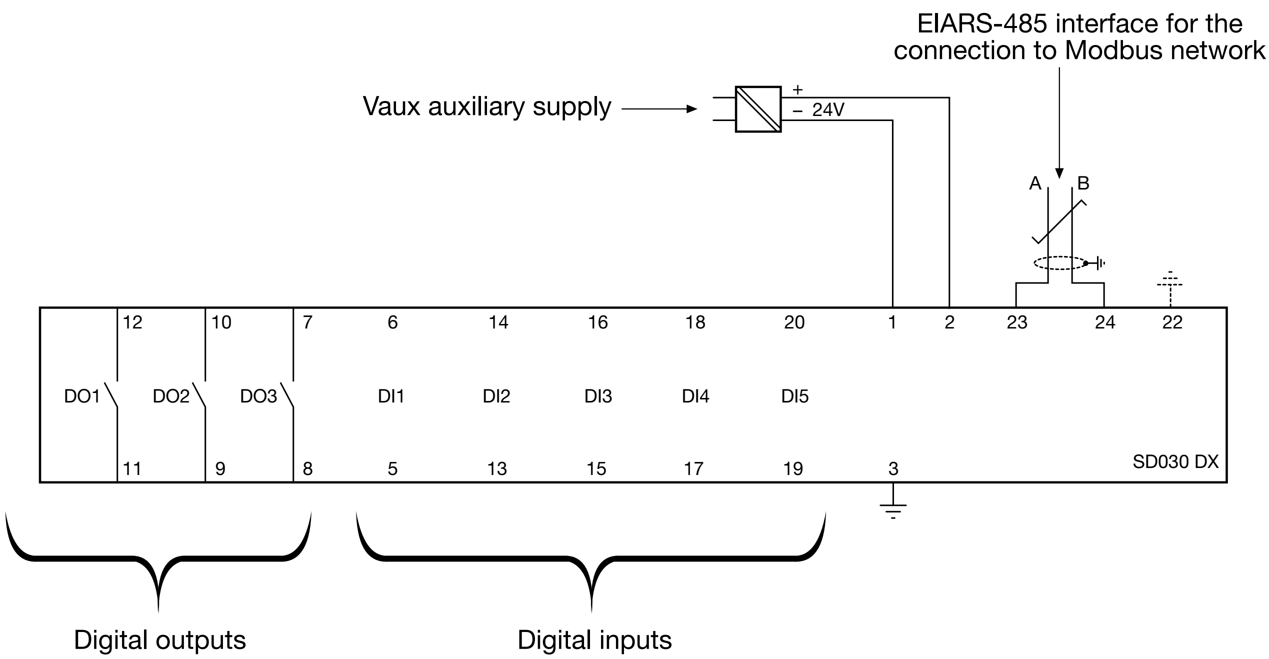
1) the circuit-breakers and the switch-disconnectors which can be remote operated;

2) the accessories, to be mounted on the circuit-breaker, through which it is possible to actuate the commands;

3) the type of command which can be performed.

Circuit-breaker type	Accessories for the command actuation	Commands
T1-T2-T3	Solenoid operator (MOS)	Opening/Closing
T4-T5-T6	Stored energy motor operator (MOE)	Opening/Closing
T7M, X1	SOR: shunt opening release SCR: shunt closing release YR: reset coil M: geared motor for the automatic charging of the closing springs	Opening Closing Reset
E1 ÷ E6	YO: shunt opening release YC: shunt closing release YR: reset coil M: geared motor for the automatic charging of the closing springs	Opening Closing Reset
Disconnector type		
T1D-T3D	Solenoid operator (MOS)	Opening/Closing
T4D-T5D-T6D	Stored energy motor operator (MOE)	Opening/Closing
T7DM, X1B/MS	SOR: shunt opening release SCR: shunt closing release M: geared motor for the automatic charging of the closing springs	Opening Closing
E1/MS ÷ E6/MS	YO: shunt opening release YC: shunt closing release M: geared motor for the automatic charging of the closing springs	Opening Closing

Figure 20: Circuit diagram of SD030DX



The proper wirings for a correct functioning of SD030DX are connected to:

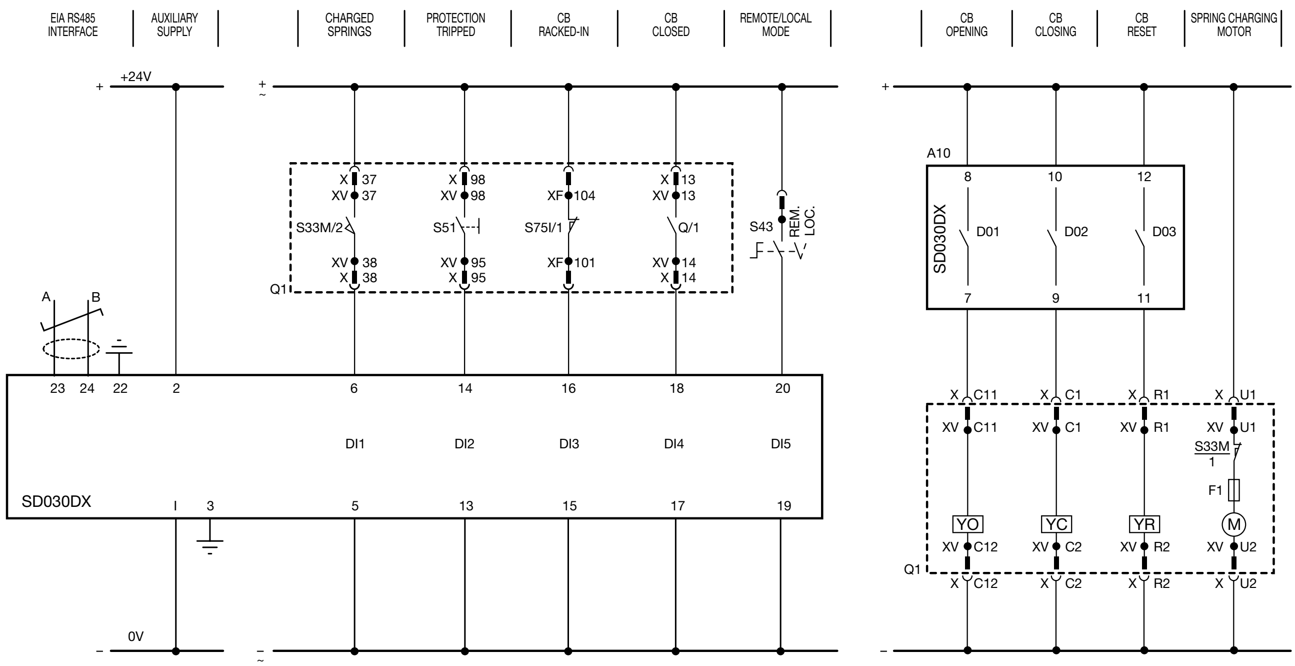
- the auxiliary circuits of the circuit-breaker through DI inputs and DO outputs, so that the unit can interact with the CB and make it possible command actuation (opening, closing, reset) and the detection of CB state;
- the Modbus network, through EIA RS-485 serial interface, to communicate with the supervision system (PC, PLC or SCADA);
- the Vaux auxiliary supply.

As an example, Figure 21 shows the wiring diagram of the SD030DX unit to an air circuit-breaker type Emax E6.

In order to function, SD030DX unit needs to be supplied by an auxiliary voltage Vaux having the following characteristics:

Characteristics of the auxilary voltage	SD030DX
Supply voltage	24 V dc ± 20%
Maximum ripple	± 5%
Rated power @24 V	2 W

Figure 21: Wiring diagram of SD030DX for a CB type Emax E6



4.6 Front panel interface HMI030

HMI030 is the visualization unit to be installed on the panel front, for air circuit-breakers series Emax and Emax X1, for moulded-case circuit-breakers Tmax T, and SACE Tmax XT equipped with the following electronic trip units:

Circuit-breakers	Trip units
Emax E1÷E6	PR121/P-PR122/P-PR123/P-PR122/DC(*) -PR123/DC(*)
Emax X1	PR331/P-PR332/P-PR333/P
Tmax T7	PR331/P-PR332/P
Tmax T4-T5-T6	PR222DS/PD-PR223DS-PR223EF
SACE Tmax XT2-XT4(*)	Ekip LSI, Ekip LSIG, Ekip E-LSIG, Ekip M-LRIU

(*) use HMI030 with 3.00 or following SW version

It is a device which, through a display, allows the electrical quantities of the plant and the information available in the connected trip unit to be displayed.
Before completing the installation of HMI030, by acting on the suitable selector positioned on the back of the device, it is possible to choose one of the selected operation mode:

- Ammeter mode (A)
In this mode it is possible to display the values of the currents in the three phases and in the neutral based on the trip unit connected. Moreover, it is possible to display the maximum current value and the phase passed through by the maximum current, referred to the latest acquisition from the Measure History of the trip unit.
This information is available if, in case of Modbus communication, HMI030 unit is operating in Master mode.

- Voltmeter Mode (V)
In this mode it is possible to display the values of the phase voltages V1N, V2N, V3N and the values of the line-to-line voltages V12, V23, V31.
In this mode, the information of the Measure History of the trip unit cannot be displayed.

Ammeter mode (A)

	E1÷E6-X1-T7	E2÷E6	T4-T5-T6	XT2-XT4	
	PR12x/P-PR33X/P	PR12X/DC	PR222DS/PD-PR223DS-PR223EF	Ekip LSIG/LSI - Ekip E-LSIG	Ekip M-LRIU
Phase currents (I_{L1}-I_{L2}-I_{L3})	■	■	■	■	■
Neutral current (I_{Ne}) (*)	■		■	■	
Measures history (currents)	■	■			

(*) Measures available in the presence of the neutral (with four-pole circuit-breaker or three-pole circuit-breaker + CT for external neutral conductor)

Voltmeter mode (V)

	E1÷E6-X1-T7	E2÷E6	T4-T5-T6		XT2-XT4
	PR122/P-PR123/P PR332/P-PR333/P	PR12X/DC	PR223EF	PR223DS	Ekip E-LSIG
Phase voltages (V_{1N}-V_{2N}-V_{3N}) (*)	■	■	■	■	■
Residual voltage (*)	■			■	■
Line to line voltages (V_{12}-V_{23}-V_{31}) (**)	■		■	■	■

(*) Measures available in the presence of the measuring module (PR120/V for Emax E1÷E6, PR330/V for Emax X1 and Tmax T7, VM210 for Tmax T4-T5-T6) and in the presence of the neutral
(**) Measures available in the presence of the measuring module (PR120/V for Emax E1÷E6, PR330/V for Emax X1 and Tmax T7, VM210 for Tmax T4-T5-T6)

- Wattmeter Mode (W)

In this mode, according to the trip unit connected, it is possible to display the values of active power P, reactive power Q and apparent power S (total and phase).

- Custom Mode (A, V, W…)

In this mode it is possible to display the values relevant to Amperometer, Voltmeter and Wattmeter modes and, according to the trip unit connected, also other information, such as: power factor (cosφ), frequency (f), current peak factor, active E(P), reactive E(Q) and apparent E(S) energy and the data relevant to the latest trip (e.g.: tripped protection and value of tripped current).

Wattmeter mode (W)

	E1÷E6-X1-T7	E2÷E6	T4-T5-T6	XT2-XT4
	PR122/P-PR123/P PR332/P-PR333/P	PR12X/DC	PR223DS	Ekip E-LSIG
Phase active power (P1-P2-P3) (*)	■		■	■
Phase reactive power (Q1-Q2-Q3) (*)	■		■	■
Phase apparent power (S1-S2-S3) (*)	■		■	■
Total active power (P) (**)	■	■	■	■
Total reactive power (Q) (**)	■		■	■
Total apparent power (S) (**)	■		■	■

(*) Measures available in the presence of the measuring module (PR120/V for Emax E1÷E6, PR330/V for Emax X1 and Tmax T7, VM210 for Tmax T4-T5-T6) and in the presence of the neutral conductor
(**) Measures available in the presence of the measuring module (PR120/V for Emax E1÷E6, PR330/V for Emax X1 and Tmax T7, VM210 for Tmax T4-T5-T6)

Custom mode (A,V,W…)

	E1÷E6-X1-T7		E2÷E6	T4-T5-T6			XT2-XT4		
	PR121/P-PR331/P	PR122/P-PR123/P PR332/P-PR333/P	PR12X/DC	PR222DS/PD	PR223EF	PR223DS	Ekip E-LSIG	Ekip LSIG/LSI	Ekip M-LRIU
Phase currents (I_{L1}-I_{L2}-I_{L3})	■	■	■	■	■	■	■	■	■
Neutral current (I_{Ne}) (*)	■	■		■	■	■	■	■	
Measures history (currents)	■	■	■						
Phase voltages (V_{1N}-V_{2N}-V_{3N}) (**)		■	■		■	■	■		
Residual voltage (**)		■				■	■		
Line to line voltages (V_{12}-V_{23}-V_{31}) (***)		■			■	■	■		
Phase active powers (P1-P2-P3) (**)		■				■	■		
Phase reactive powers (Q1-Q2-Q3) (**)		■				■	■		
Phase apparent powers (S1-S2-S3) (**)		■				■	■		
Total active power (P) (***)		■	■			■	■		
Total reactive power (Q) (***)		■				■	■		
Total apparent power (S) (***)		■				■	■		
Total power factor ($cosφ_{tot}$) (***)		■				■	■		
Frequency (***)		■				■	■		
Phase peak factor		■				■			
Peak factor of the neutral (*)		■				■			
Total active energy (***)		■	■			■	■		
Total reactive energy (***)		■				■	■		
Total apparent energy (***)		■				■	■		
Data of the latest trip	■	■	■	■	■	■	■	■	■

(*) Measures available in the presence of the neutral (with four-pole circuit-breaker or three-pole circuit-breaker + CT for external neutral conductor)
(**) Measures available in the presence of the measuring module (PR120/V for Emax E1÷E6, PR330/V for Emax X1 and Tmax T7, VM210 for Tmax T4-T5-T6) and in the presence of the neutral conductor
(***) Measures available in the presence of the measuring module (PR120/V for Emax E1÷E6, PR330/V for Emax X1 and Tmax T7, VM210 for Tmax T4-T5-T6)

On the HMI030 unit, the interface RS485 (terminals 3 and 4) and CAN (terminals 7 and 8) cannot be used simultaneously. As a consequence it is not possible to have simultaneously Modbus communication and the communication on WI internal bus (Bus CAN dedicated to ABB devices).
More than one unit HMI030 set in the same operating mode cannot be connected to the same bus.
To be able to operate, the unit HMI030 must be supplied with an auxiliary voltage (Vaux) having the following characteristics:

Supply voltage	24 V dc ± 20%
Maximum ripple	± 5%
Rated power	1.4 W @ 24 V dc

The auxiliary supply shall be provided using a galvanically isolated external power supply. Since an auxiliary supply voltage isolated from earth is required, it is necessary to use "galvanically isolated converters" complying with the Stds. IEC 60950 (UL 1950) or its equivalent IEC 60364-41 and CEI 64-8, which guarantee a common mode current or leakage current (see IEC 478/1 and CEI 22/3) not higher than 3.5 mA.

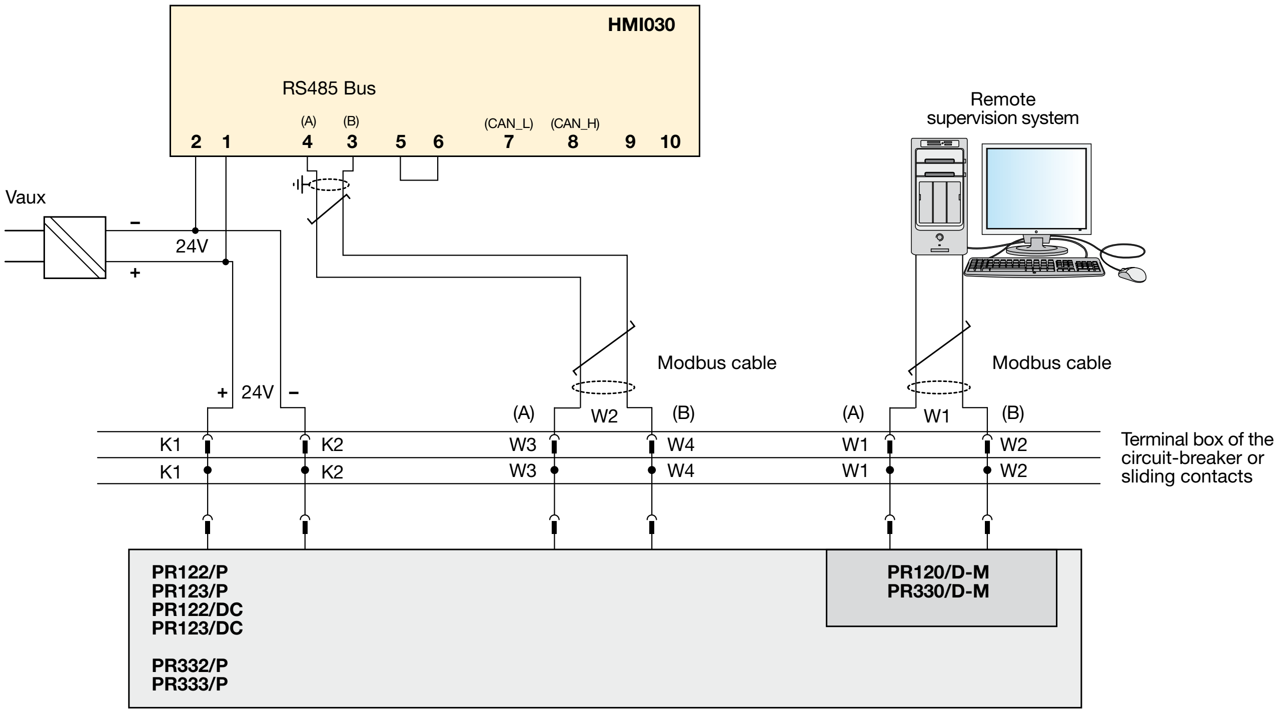
Here are some examples of wiring diagrams for the use of the unit HMI030.

For more detailed information on the use and characteristics of this device, reference must be made to the product technical manual "HMI030 Remote visualization unit" (document code 1SDH000573R0001).

Emax E1÷ E6 - Emax X1 - Tmax T7

With air-circuit-breakers type Emax E1÷E6, Emax X1 and moulded-case circuit-breakers Tmax T7, the following configurations are available:

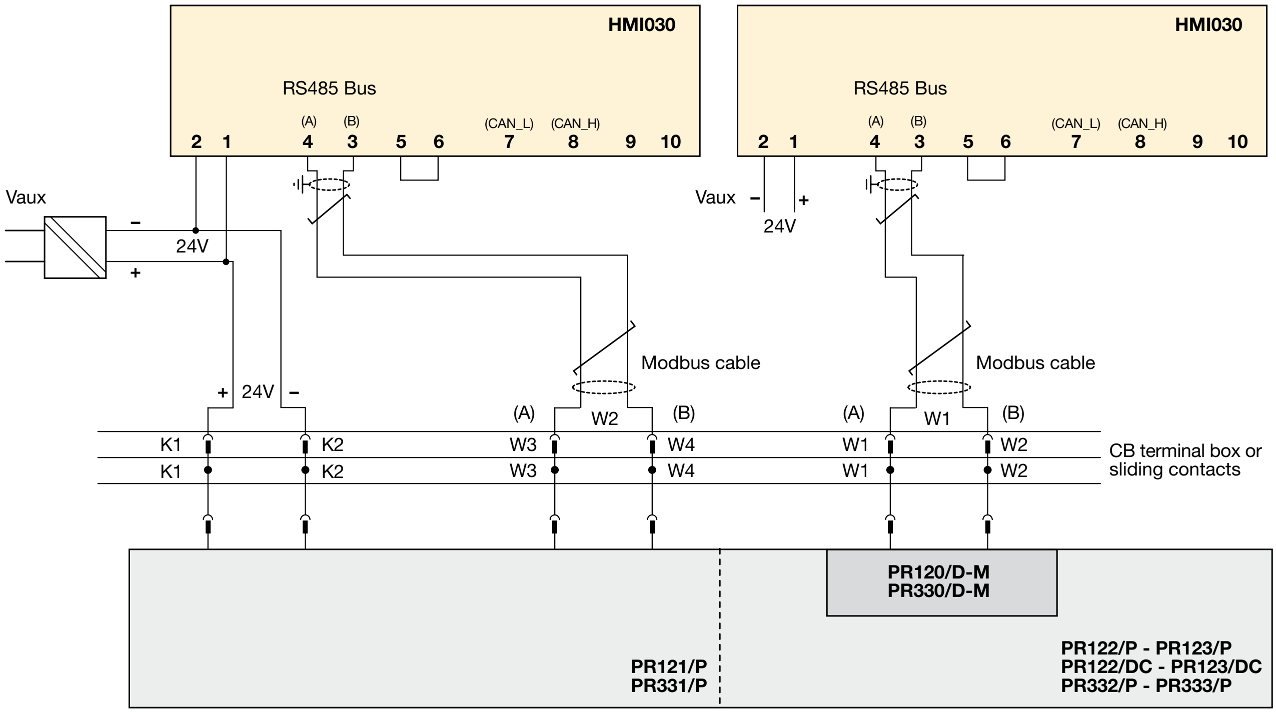
- Remote supervision and display on panel front



HMI030 unit configured in "Master" mode and Modbus communication
W1: System bus of the trip unit (terminals W1 and W2)
W2: Local bus of the trip unit (terminals W3 and W4)
K1-K2: auxiliary supply Vaux
The connection between trip unit and HMI030 shall be achieved through twisted pair cables, shielded and with characteristic impedance equal to 120 Ω (e.g.: Belden 3105 cable type or equivalent). The shield shall be connected to earth at one end of the connection.
Maximum recommended length for the connection between HMI030 and trip unit: 15 m.

In this configuration it is possible to connect to the trip unit one HMI030 unit only (on the bus W2).

- Display on panel front



HMI030 unit configured in "Master" mode and Modbus communication
W1: System bus of the trip unit (terminals W1 and W2)
W2: Local bus of the trip unit (terminals W3 and W4)
K1-K2: auxiliary supply Vaux
Maximum recommended length for the connection between HMI030 and the trip unit (on the bus W2): 15 m
(*) When the System bus W1 of the trip unit is used, the maximum recommended length for the connection between HMI030 and trip unit is 300 m.
In this case, it is necessary to:
- use PR120/D-M (PR330/D-M) communication module for the connection between HMI030 and trip unit; HMI030 shall be connected to the System bus W1 of the trip unit
- set HMI030 unit to "Master" mode; use Modbus RS485 communication interface (terminals 3 and 4)
- set the following communication parameters of the trip unit: Address: 3; Baud rate: 19200; Parity: EVEN; Stop bit : 1.

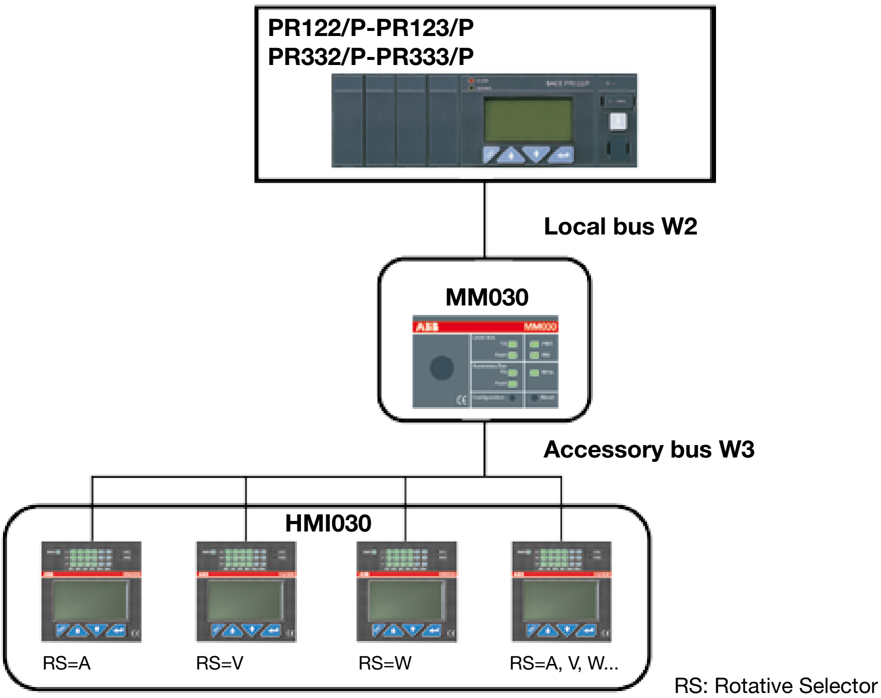
The connection between trip unit and HMI030 shall be achieved through twisted pair cables, shielded and with characteristic impedance equal to 120 Ω (e.g.: Belden 3105 cable type or equivalent). The shield shall be connected to earth at one end of the connection.

With this configuration and with trip unit type PR121/P and PR331/P, it is possible to connect only one HMI030 unit to the trip unit (on the Local bus W2).
With this configuration and with trip units type PR122/P, PR123/P, PR332/P, PR333/P, PR122/DC and PR123/DC, it is possible to connect up to two HMI030 to the trip units; the first one on the Local bus W2 and the second one on the System bus W1 (see (*))
Since they are connected to two different buses, the two HMI030 units can be set to the same operating mode.

- Display on panel front with more units HMI030

It is possible to connect up to four HMI030 units to the same trip unit (on the same bus) if the following conditions are complied with:
- trip unit type PR122/P-PR123/P or PR332/P-PR333/P;
- each unit HMI030 has SW version 2.00 or following ones and is configured in "Slave" mode; Modbus RS485 communication interface is used (terminals 3 and 4);
- MM030 unit is present (supply with auxiliary voltage at 24 V d.c. (Pn=2.5 W @24V));
- four different operating modes (Ammeter, Voltmeter, Wattmeter and Custom) are selected for each HMI030.

Principle scheme



W2: Local bus of the trip unit (terminals W3 and W4) and of the unit MM030 (terminals 10 and 11)
W3: Accessory bus of MM030 unit (terminals 13 and 14)
Maximum recommended length for the Local bus W2: 15 m
Maximum recommended length for the Accessory bus W3: 300 m
For the connections twisted pair cables, shielded and with characteristic impedance equal to a 120 Ω (e.g.: cable type Belden 3105 or equivalent).
For the connection between trip unit and MM030, it is advisable to ground the shield at the end of the connection towards the trip unit.
As regards wiring of the Accessory bus W3, it is advisable to ground the shield at the end of the connection towards MM030 unit.
As for wiring, the instructions of the product technical manual "Flex Interfaces for Accessory Bus" should be followed.

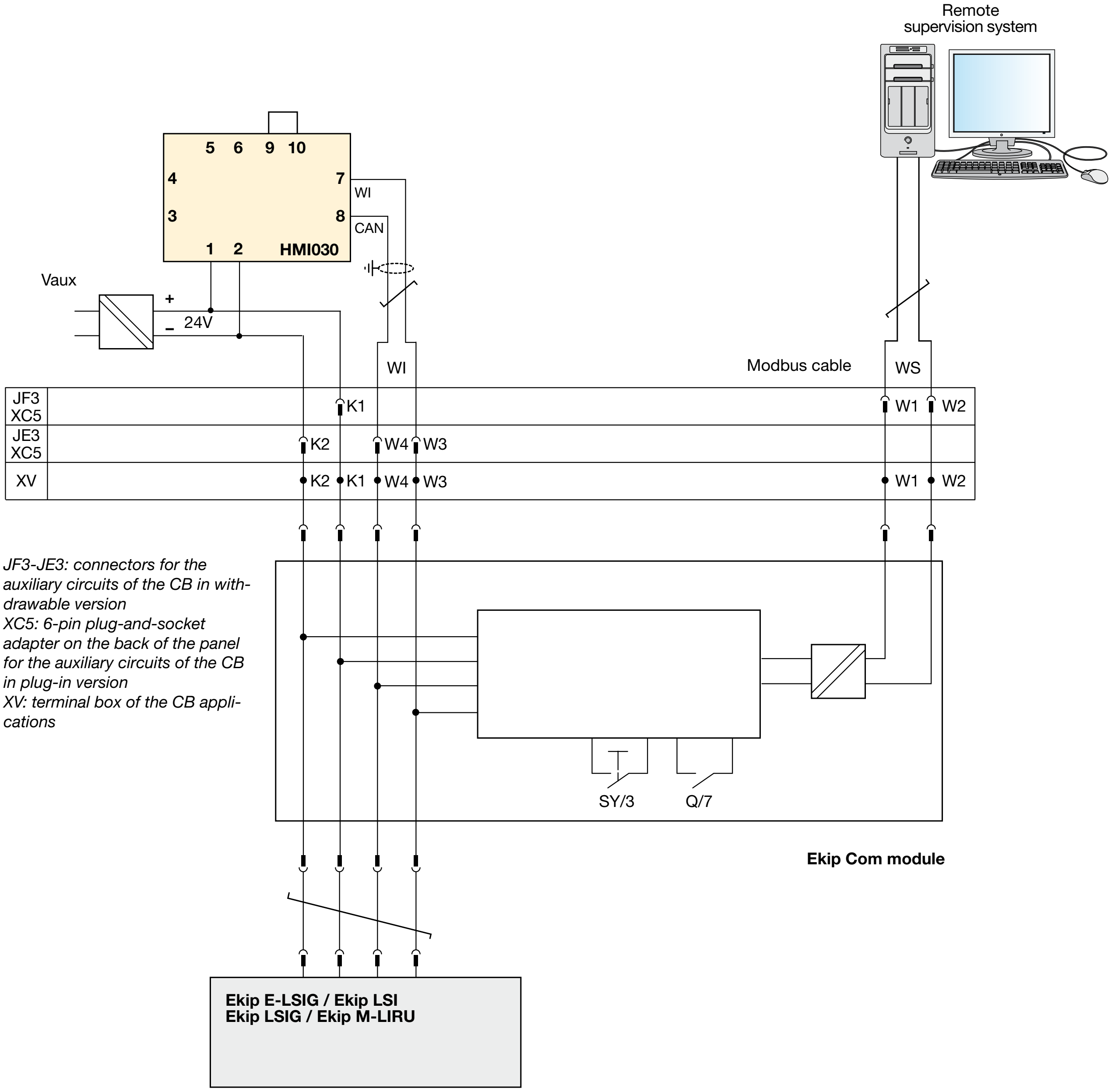
With PR121/P and PR331/P trip units it is possible to connect up to two HMI030 units on which two different operating modes have been selected: Ammeter (A) and Custom (A, V, W…).
In this configuration, to manage the information exchange between the trip unit and HMI030 interface devices, MM030 unit must be used.
MM030 is a microprocessor-based device provided with two different communication buses:
- one Local bus (W2), for the connection and communication with the trip unit (via the System bus W1 of the trip unit);
- one Accessory bus (W3), for the connection and communication with HMI030 units.

In this way, MM030 receives the data from the trip unit (via the bus W2) and sends it to the visualization units HMI030 connected to it (via the bus W3) so that it is possible to display on the panel front the measured electrical quantities.
For more detailed information see the product technical manual "Flex interfaces for accessory Bus" (document code: 1SDH000622R0001).

Moulded-case circuit-breakers type SACE Tmax XT2 – XT4

With the moulded-case circuit-breakers series SACE Tmax XT2 and XT4 equipped with Ekip E-LSIG, Ekip LSI, Ekip LSIG and Ekip M-LIRU electronic trip units are possible with the two following configurations:

- Remote supervision and display on panel front



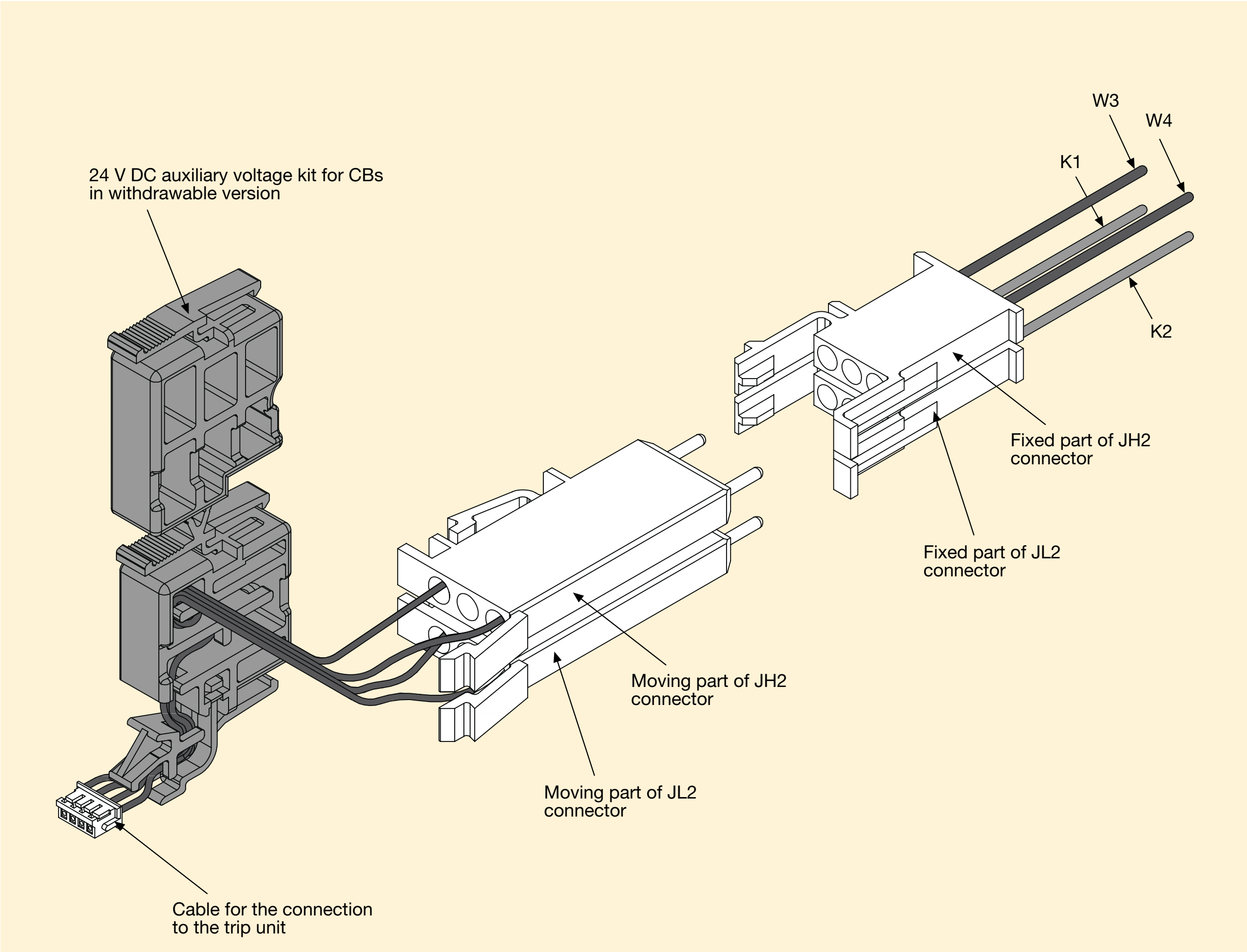
JF3-JE3: connectors for the auxiliary circuits of the CB in withdrawable version
XC5: 6-pin plug-and-socket adapter on the back of the panel for the auxiliary circuits of the CB in plug-in version
XV: terminal box of the CB applications

This configuration can be achieved if HMI030 is provided with SW version 3.00 or following ones.
HMI030 configured in "Master" mode and communication via Internal bus WI
WI: Internal bus of the trip unit (CAN interface reserved for ABB devices; cables W3 and W4 of Ekip Com module)
WS: System bus of the trip unit (cables W1 and W2 of Ekip Com module)
K1-K2: auxiliary supply Vaux
Maximum length of the connection between HMI030 and trip unit: 15 m.
The connection between trip unit and HMI030 shall be achieved through twisted pair cables, shielded and with characteristic impedance equal to 120 Ω (e.g.: Belden 3105 cable type or equivalent). The shield shall be connected to earth at one end of the connection.

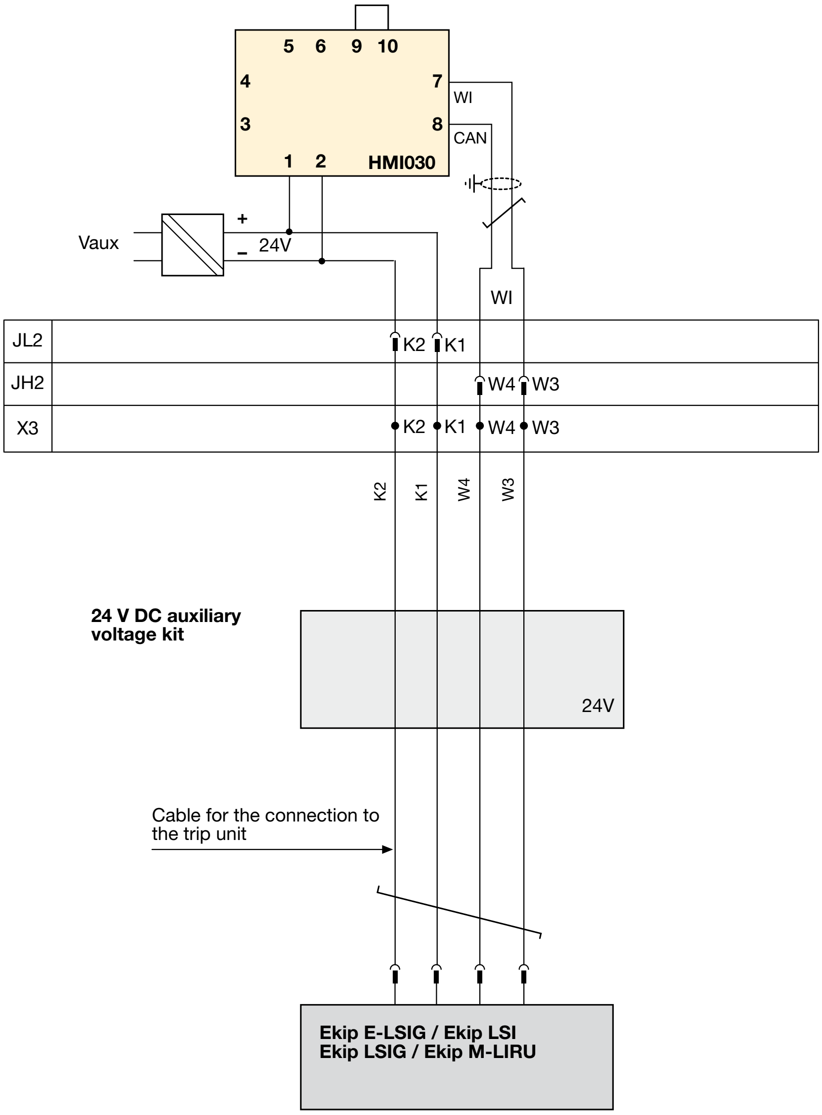
- Display on panel front

To achieve this configuration it is possible to use the suitable 24 V DC auxiliary voltage kit to connect the electronic trip units type Ekip E-LSIG, Ekip LSI, Ekip LSIG and Ekip M-LRIU to HMI030 unit.
The 24 V DC auxiliary voltage kit is available in two versions, one for the circuit-breakers in fixed/plug-in version and one for the circuit-breakers in withdrawable version.

Figure 22: 24 V DC auxiliary voltage kit for circuit-breakers in withdrawable version



JL2-JH2: connectors for the auxiliary circuits of the circuit-breakers in withdrawable versions



JL2-JH2: connectors of the 24 V DC auxiliary voltage kit for CB in withdrawable version
X3: 6-pin plug-and-socket adapter on the back of the panel for the 24 V DC auxiliary voltage kit for CB in plug-in version

This configuration can be achieved if HMI030 unit is provided with SW version 3.00 or following ones.
HMI030 is configured in "Master" mode and with communication via Internal bus WI
The 24 V DC auxiliary voltage kit must be used
K1-K2: auxiliary supply Vaux
WI: Internal bus of the trip unit (CAN Interface reserve for ABB devices; cables W3 and W4 of the 24 V DC auxiliary voltage kit)
Maximum length of the connection between HMI030 and trip unit: 15 m
For lengths exceeding 15 m and up to 300 m it is necessary to:

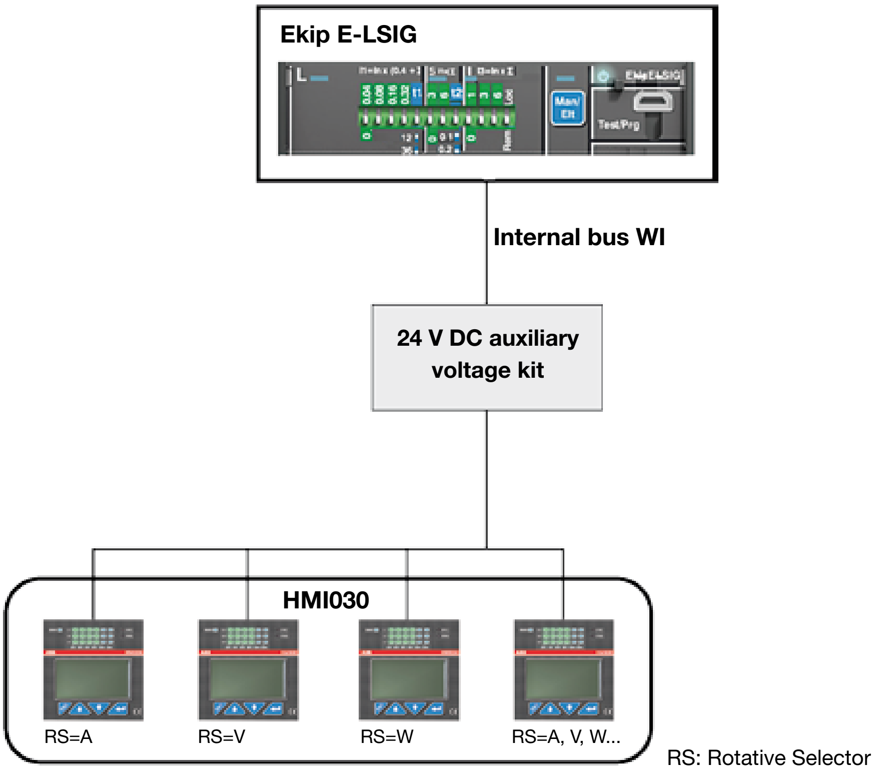
- set the unit HMI030 to "Master" mode and use Modbus RS485 communication interface (terminals 3 and 4)
- use the communication module type Ekip Com, instead of the 24 V DC auxiliary voltage kit, for the connection between HMI030 and trip unit; HMI030 unit is to be connected to the System bus WS of the trip unit (cables W1 and W2 of Ekip Com module)
- set the following communication parameters of the trip unit: Address: 247; Baud rate: 19200; Parity: EVEN; Stop bit: 1.

The connection between trip unit and HMI030 shall be achieved through twisted pair cables, shielded and with characteristic impedance equal to 120 Ω (e.g.: Belden 3105 cable type or equivalent). The shield shall be connected to earth at one end of the connection.

- Display on panel front with more units HMI030

With this configuration it is possible to connect up to four HMI030 units to the same trip unit (on the same bus) if the following conditions are complied with:
- trip unit type Ekip E - LSIG;
- each unit HMI030 has SW version 3.00 or following ones, it is configured in "Master" mode and communicates via the Internal bus WI (terminals 7 and 8);
- four different operating modes (Ammeter, Voltmeter, Wattmeter and Custom) are selected for each HMI030.

Principle scheme



WI: Internal bus of the trip unit (CAN interface reserved for ABB devices; cables W3 and W4 of the 24V DC auxiliary voltage kit)
Maximum recommended length for the Internal bus WI: 15 m
For the lengths exceeding 15 m and up to 300 m it is necessary to:
- set each unit type HMI030 in "Master" mode and use Modbus RS485 communication interface (terminals 3 and 4)
- use the communication module type Ekip Com, instead of the 24 V DC auxiliary voltage kit
- use the System bus WS of the trip unit (cables W1 and W2 of Ekip Com module) for the connection of the trip unit to HMI030 units
- set the following communication parameters of the trip unit: Address: 247; Baud rate: 19200; Parity: EVEN; Stop bit: 1.

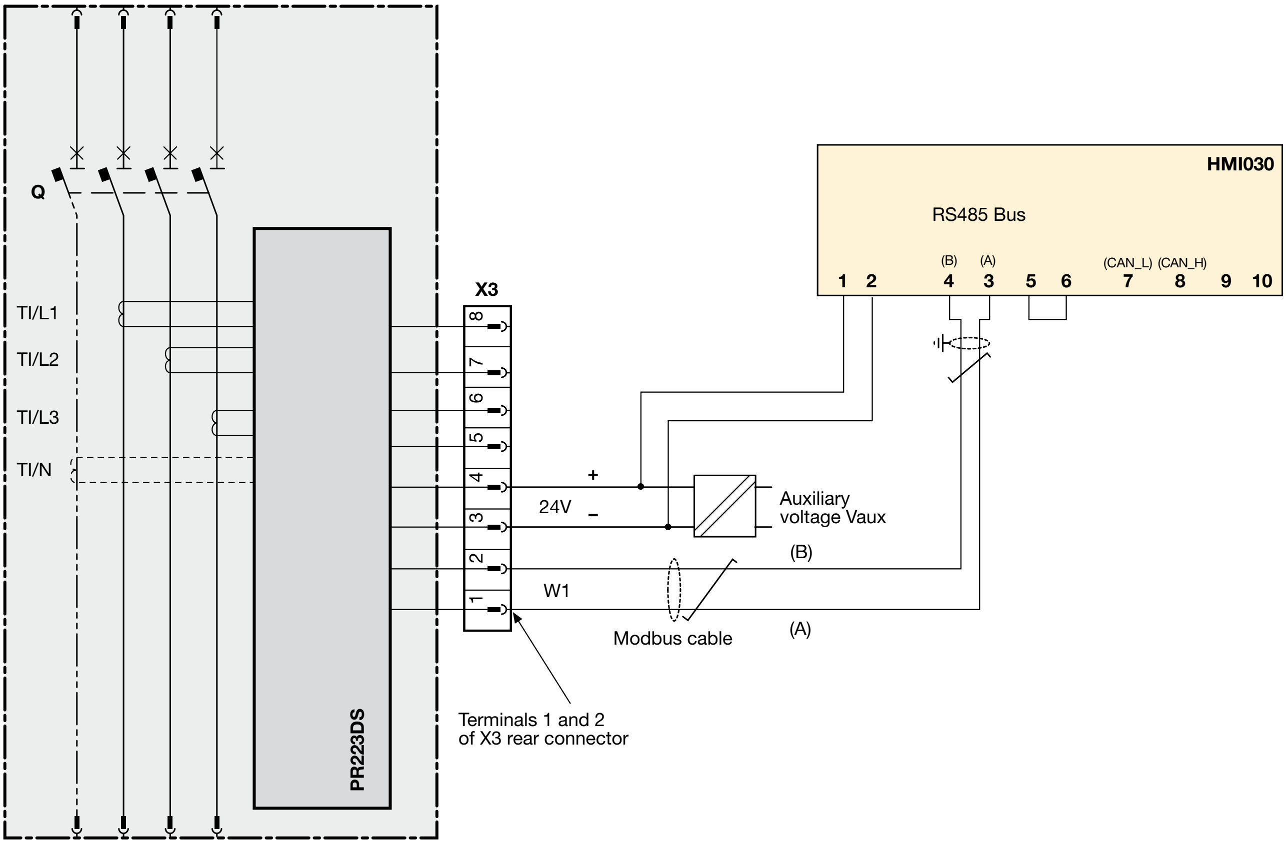
For the wiring between the trip unit and HMI030 units, use twisted pair cables, shielded and with characteristic impedance equal to 120 Ω (e.g.: cable type Belden 3105 or equivalent). It is advisable that the shield is connected to earth at the end of the connection towards the trip unit.

With Ekip LSI, Ekip LSIG or Ekip M-LRIU trip units it is possible to connect on the same bus WI, up to two HMI030 units on which two different operating mode have been selected: Ammeter (A) and Custom (A, V, W…).

Moulded-case circuit-breakers type Tmax T4-T5-T6

With moulded-case circuit-breakers type Tmax T4-T5-T6 equipped with electronic trip units PR222DS/PD, PR223DS and PR223EF, the following configurations are possible:

- Display on front panel



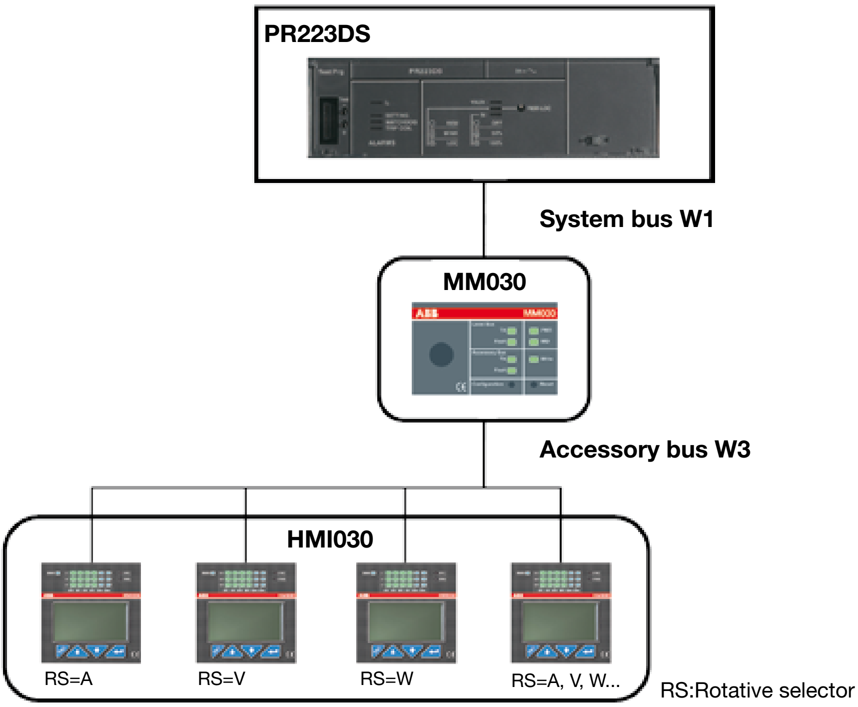
HMI030 in “Master” mode and Modbus communication
W1: System bus of the trip unit
Maximum recommended length for the System bus W1: 300 m
The connection between trip unit and HMI030 shall be achieved through twisted pair cables, shielded and with characteristic impedance equal to 120 Ω (e.g.: cable type Belden 3105 or equivalent). The shield shall be connected to earth at one end of the connection.
For the use in this configuration the following communication parameters of the trip unit must be set:
- address: 247
- Baud rate: 19200 bit/s
- parity: EVEN
- stop bit: 1.

In this configuration only one HMI030 can be connected to the trip unit (on the System bus W1).

- Display on panel front with more units HMI030

It is possible to connect up to four HMI030 units to the same trip unit (on the same bus) if the following conditions are complied with:
- PR223DS trip unit;
- the following communication parameters of the trip unit are set: Address: 247; Baud rate: 19200 bit/s; Parity: EVEN; stop bit: 1;
- four different operating modes (Ammeter, Voltmeter, Wattmeter and Custom) are selected for each HMI030;
- each unit HMI030 has SW version 2.00 or following ones and is configured in “Slave” mode; Modbus RS485 communication interface is used (terminals 3 and 4);
- MM030 unit is present (supply with auxiliary supply voltage at 24 V d.c. (Pn=2.5 W @24V)).

Principle scheme



W1: System bus of the trip unit communicating with the Local bus (W2) of MM030 unit (terminals 10 and 11)
W3: Accessory bus of MM030 unit (terminals 13 and 14)
Maximum recommended length for the connection between trip unit and MM030 (System bus W1): 200 m; maximum recommended length for the Accessory bus W3: 300 m. For the connections, use twisted pair cables, shielded and with characteristic impedance equal to a 120 Ω (e.g.: cable type Belden 3105 or equivalent).
In the connection between trip unit and MM030 device (System bus W1), it is advisable that the shield is earthed at the end of the connection towards the trip unit. When wiring Accessory bus W3, it is advisable that the shield is connected to earth at the end of the connection towards MM030 unit.
As for wiring, the instructions of the product technical manual “Flex Interfaces for Accessory Bus” should be followed.

With PR223EF trip units, up to three units HMI030 can be connected on which three different operating modes have been selected: Ammeter (A), Voltmeter (V), and Custom (A, V, W…).
With PR222DS/PD trip units up to two units HMI030 can be connected on which two different operating modes have been selected: Ammeter (A) and Custom (A, V, W…).
In this configuration, to manage the information exchange between the trip unit and HMI030 interface devices, MM030 unit must be used.
MM030 is a microprocessor-based device provided with two different communication buses:
- one Local bus (W2), for the connection and communication with the trip unit (via the System bus W1 of the trip unit);
- one Accessory bus (W3), for the connection and communication with HMI030 units.
Thus MM030 receives the data from the trip unit (via the bus W2) and sends it to the visualization units HMI030 connected to it (via the bus W3) so that it is possible to display on the panel front the measured electrical quantities.
For more detailed information see the product technical manual “Flex Interfaces for Accessory Bus” (document code: 1SDH000622R0001)”.

4.7 Modbus RS-485 network (Rules for a correct wiring)

The wiring of the industrial communication systems presents some differences in comparison with that used for power cabling and this may put into difficulties the installer if he is not experienced in Modbus communication networks.
A Modbus RS-485 system puts into communication a Master device with one or more Slave devices. From now on, only ABB SACE low voltage circuit-breakers shall be considered as Slave devices, even if wiring is similar for all Modbus devices.
Here is a presentation of the main rules to comply with for the wiring of this type of networks.

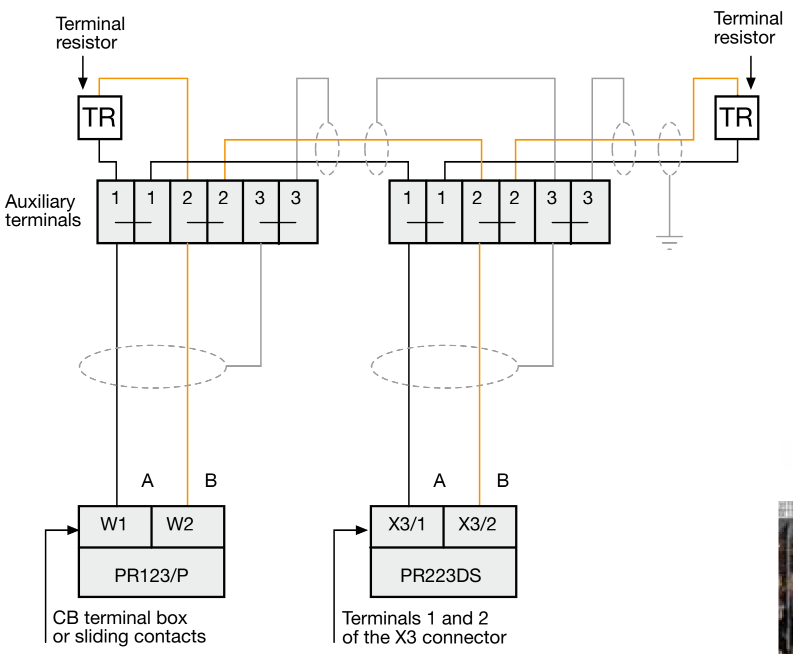
1. Connection port
Each device is equipped with a communication port with two terminals, conventionally called A and B.
The communication cable is connected into these two terminals, so that all the devices involved by the communication are connected in parallel.
All the terminals A and B shall be connected together, respectively A to A and B to B; in case of reversed connections A to B of a device, besides making communication impossible for them, the whole communication system might not work properly due to the continuous incorrect voltages present on the device terminals badly connected.

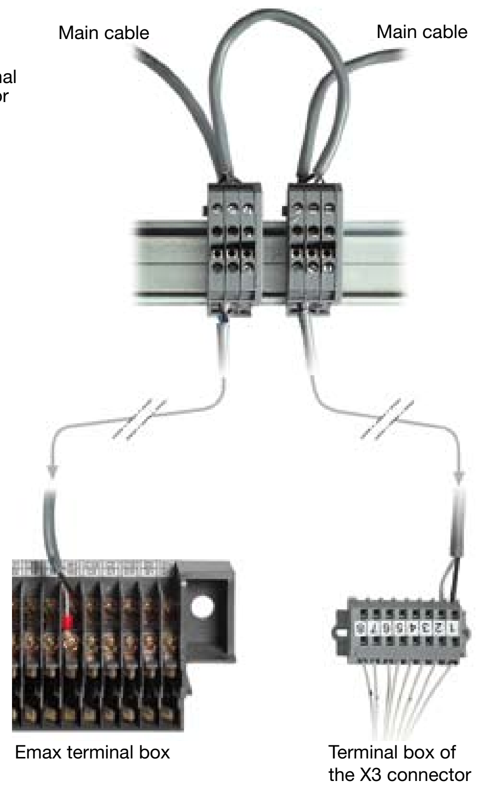
In ABB SACE circuit-breakers, the communication terminals are represented as shown in the following table:

Circuit-breaker	Trip uit	Terminal A (-)	Terminal B (+)	Note
Emax	PR122/P e PR123/P	W1	W2	CB delivery terminal box or sliding contacts
Emax X1 Tmax T7/T7M	PR332/P e PR333/P	W1	W2	CB delivery terminal box or sliding contacts
Tmax T4-T5-T6	PR222DS/PD PR223EF PR223DS	X3/1	X3/2	terminals 1 and 2 of the rear connector X3
SACE Tmax XT2 - XT4	Ekip E-LSIG Ekip LSIG Ekip LSI Ekip M-LRIU	cable W1	cable W2	- cables W1 and W2 outgoing from Ekip Com module (with fixed circuit-breaker); - cables W1 and W2 outgoing from fixed part (the socket) of JF3 connector for withdrawable circuit-breakers; - cables outgoing from clamps 1 (for W1) and 2 (for W2) of the fixed part (the socket) of the 6-pin (XC5) plug-and-socket adapter on the back of the panel for plug-in circuit-breakers.

This table shows the information given in the wiring diagrams of Annex C.

Figure 23: Electrical wiring diagram of an Emax and a Tmax to the Modbus network





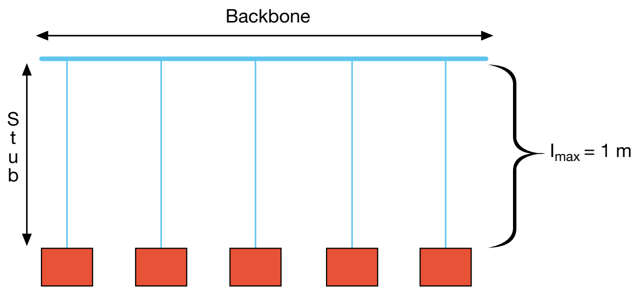
In order to avoid errors when many devices are connected, it is advisable to use the same color for all the wires connected respectively to the terminals A and B of the different devices (e.g. white for A and blue for B); this makes easier the identification of reversed wiring.
Also on the Master device, whatever it is, the communication port has two connections which correspond to A and B. Some manufactures indicate them with Tx- and Tx+, or with Data- and Data+, or simply with RS-485+ and RS-485-.

2. Device connection
Unlike what happens in many energy distribution systems, the modality of connection in parallel of the devices must be taken into account.

The system RS-485, used for Modbus communication of ABB SACE circuit-breakers, requires a main cable (bus or backbone) with length not exceeding 700 m, to which all the devices must be connected through branches (called also stubs) as short as possible.
For ABB SACE circuit-breakers the stubs shall not exceed the maximum length of 1 m.

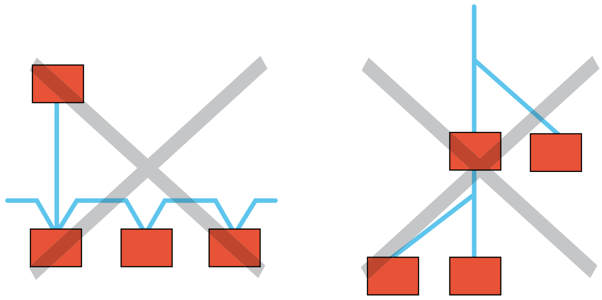
The presence of longer stubs could cause reflections of the signals with the possible induction of disturbances and consequent errors in the data reception.
Figure 23a shows the example of a correct bus connection.

Figure 23a: Network with bus structure



On the contrary, Figure 24 shows some examples of wrong bus connection.

Figure 24: Examples of wrong bus connection

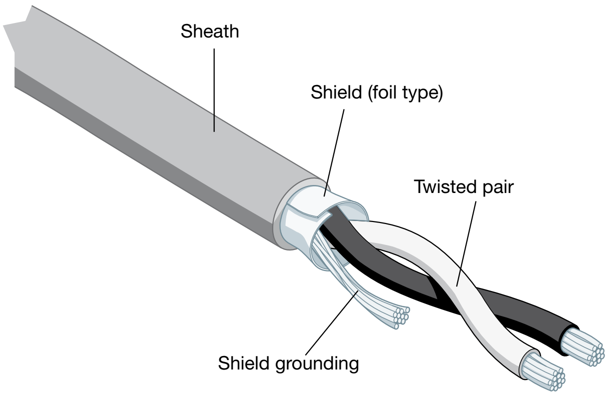


3. Maximum distance and maximum number of devices
The main bus shall have a total maximum length of 700 m. This distance does not include the stubs (which, however, must be short).
The maximum number of devices which can be connected to the main bus is 32, Master included.

4. Use of repeaters
In order to increase the extension of the Modbus network, repeaters can be used. They are devices which amplify and regenerate the signals and have two communication ports transferring signals from one port to the other one.
When using a repeater, the main cable is divided into different segments, each of which can reach a length of 700 m and connect up to 32 devices (this number includes the repeaters).
The maximum number of repeaters which is advisable to connect in series is 3. A larger number may cause excessive delays in the communication system.

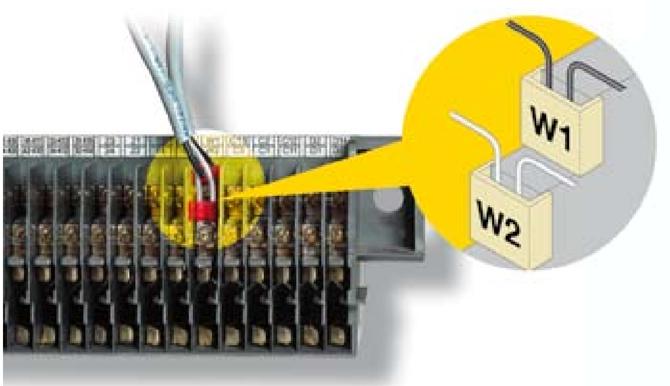
5. Type of cable to be used
The cable to be used is a shielded twisted pair cable (type for telephone).
ABB SACE recommends a cable type Belden 3105A, but it is possible to use also other cables with equivalent characteristics.
The pair cable is formed by two insulated conductors twisted together. This helps to improve the immunity against electromagnetic disturbances, because the cable forms a series of coils, each of them turned in the opposite direction with respect to the following one: thus, a possible magnetic field in the environment passes through each pair of coils in the opposite direction and consequently its effect is very reduced (theoretically, the effect on each coil is exactly contrary to that on the following one and therefore the resulting effect is cancelled).
The shielding can be "braided" (formed by a mesh of fine conducting wires) or "foil" (consisting in a metal foil wrapped around the conductors): the two types are equivalent.

Figure 25: Detail of a shielded twisted pair cable



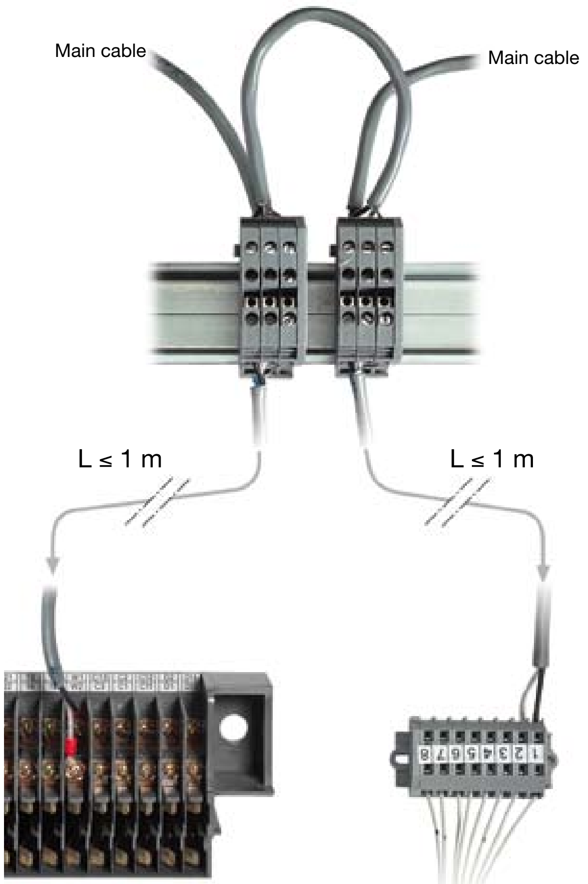
6. Connection to the terminals
In some countries it is allowed to insert two cables into the same screw terminal. In such case, it is possible to connect the main cable directly to the terminals of the circuit-breaker, without a stub as shown in Figure 26.

Figure 26: Connection of the main cable directly to the terminals of the circuit-breakers



Instead, if each terminal can hold a single wire only, it is necessary to create a real stub by using three auxiliary terminals for each circuit-breaker to be connected, as shown in Figure 27.

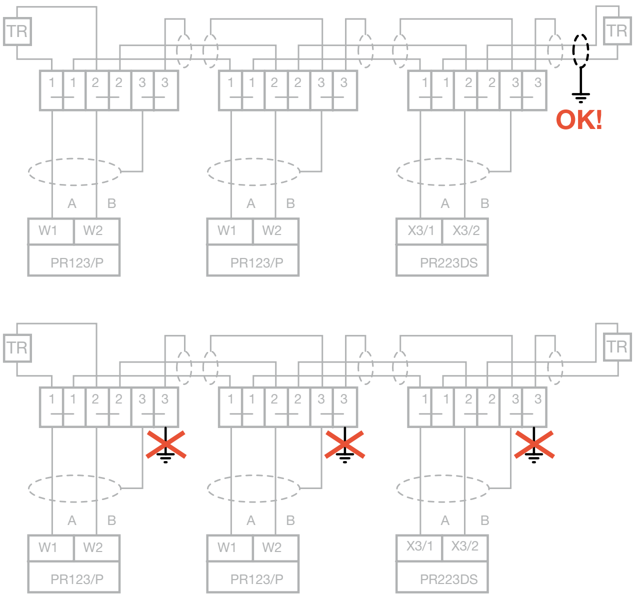
Figure 27: Connection to the circuit-breaker through auxiliary terminals



7. Grounding of shielding

The shield of the cable must be connected to ground at a single point. Usually grounding is at one end of the main cable. Figure 28 shows some correct and incorrect examples of grounding.

Figure 28: Examples of correct and incorrect grounding of shielding



8. Terminating resistors

In order to avoid reflections of the signal, a 120 Ohm terminating resistor must be mounted at both ends of the main cable.

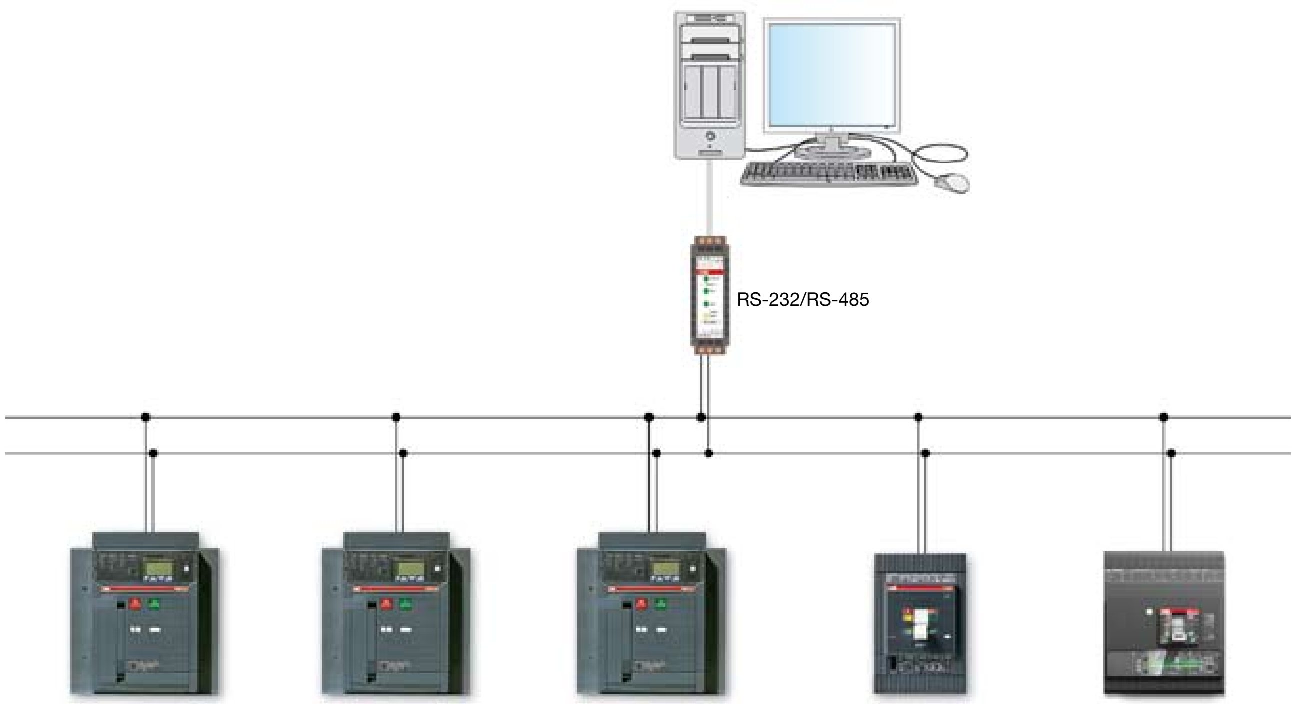
An internal terminating resistance is not provided for ABB SACE devices type new Emax, Emax X1 air circuit-breakers and Tmax moulded-case circuit-breakers.
If other devices are connected in addition to ABB SACE circuit-breakers, it is necessary to verify whether they are equipped or not with terminating resistors (in this case, it is usually possible to activate or deactivate it).

Terminating resistors must be used only at both ends of the main cable.
If the total length of the main cable is lower than 50 m, the terminating resistors at both ends of the main cable can be avoided.

9. Connection to a personal computer

If the master used is a personal computer, the connection to the bus generally occurs through a serial converter RS-232/RS-485 as shown in the following Figure.

Figure 29: Connection of a PC to the bus through a serial converter RS-232/RS-485 ILPH



4.7.1 Modbus RTU system functioning

The traffic of information on the bus is managed through a procedure type Master/Slave with a PC or PLC as Master and the circuit-breakers as Slaves. The Master defines all the traffic on the bus and only it can start the communication. It transmits data and/or commands to the Slaves and requires them to send the data in their turn. The Slaves transmit on the network only when required by the Master.
The Slaves cannot communicate between them directly: for instance, in order to transfer a datum from one Slave to another one, it is necessary that the Master reads the datum from the first Slave and then transfer it to the second one. However, in the application context of ABB SACE circuit-breakers this operation is never necessary.
The communication sequence between each circuit-breaker (Slave) and the PC (Master) occurs as follows:

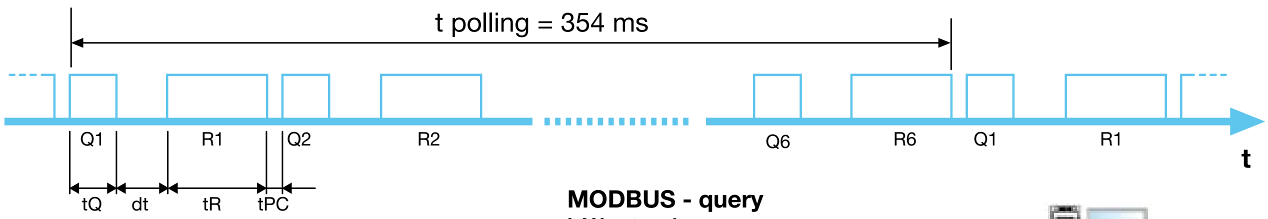
1) the PC sends a command[8] or a query on the bus
2) the queried circuit-breaker sends a response by performing the appropriate action, which may be:
   - performing the command received;
   - giving the required data or
   - informing the Master that its query cannot be satisfied.

The circuit-breakers are queried by the PC with cyclic polling, that is cyclically one after the other, so that the complete scanning of the plant is carried out within a predictable time (polling time).

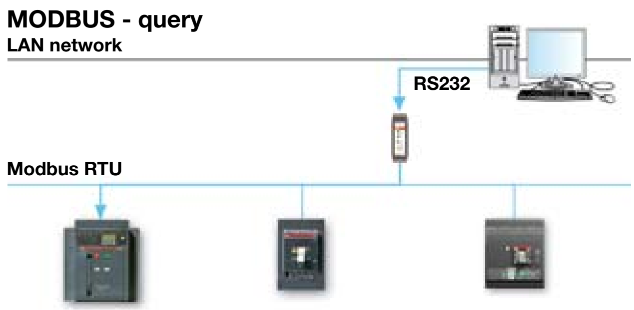
For instance, supposing we want to read the current values from 6 Tmax circuit-breakers equipped with the electronic trip unit PR222DS/PD.
For the communication sequence between each circuit-breaker and the PC, the following times are assumed:

- query time tQ (time necessary for the PC query to the circuit-breaker): 7ms
- time interval, dt, between query and response: 43ms
- response time tR (time necessary for the circuit-breaker response to the PC): 9ms.

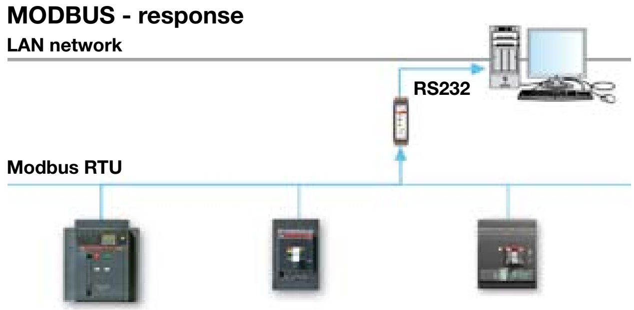
[8] The command or the request includes the identification code of the circuit-breaker to which the communication has been sent; therefore, though the transmission is received by all the devices connected to the network, only the involved device shall send a response.



Q = QUERY
(query of the PC to the circuit-breaker)



R = RESPONSE
(response sent by the circuit-breaker to the PC)



Under these suppositions, the query time for each circuit-breaker is about 59ms and, considering it constant for all the circuit-breakers, the polling time for each communication cycle shall be about: 59 × 6 = 354ms.

When calculating the polling time, the processing time of the PC, tPC, - that is the time elapsing between the end of the RESPONSE of a circuit-breaker and the start of the QUERY sent by the PC to the next circuit-breaker - is considered negligible.

To implement a communication network among more slaves in Modbus RTU protocol (it does not matter if measuring instruments, protection circuit-breakers or temperature control units), it is fundamental to have the possibility of setting the same communication parameters on all devices present in the network.

These parameters are:
- speed of data transmission, called baud rate: (e.g.:19200 bps)
- data bit (no. of bits): 8
- parity bit : Even/Odd/None
- stop bit: 1 (when parity bit = even or odd) or 2 (when parity bit = none)
- address of each slave.

Once the same baud rate, parity bit and stop bit have been set, and after having identified each slave device with its own single address, it is possible for the master to proceed with the acquisition of the information.

NOTE: A detailed description of the Modbus communication protocol can be found on the website www.modbus.org.

4.8 Ekip Connect software

Ekip Connect is a software application for personal computers (with Microsoft Windows® operating system) which allows data to be exchanged between one or more ABB low voltage equipment.
This software can be used for:
- commissioning, testing and monitoring of the Modbus RS-485 network and of the relevant connected devices;
- detection of faults and anomalies in a communication network already active;
- interaction and data exchange with the electronic trip units equipped with Modbus communication interface.

This document deals with the use of Ekip Connect software for the communication between a PC and one or more ABB devices simultaneously connected in a serial bus.
This configuration, called "Ekip Connect with serial line", is used for communication via Modbus RS-485 networks with the electronic trip units fitted with communication module (e.g.: PR12X/P with PR120/D-M module for Emax, Ekip Ekip LSI, Ekip LSIG, Ekip M-LRIU and Ekip E-LSIG with Ekip Com module for SACE Tmax XT) and with the electronic trip units which have an integrated communication interface (e.g.: PR223DS/EF, PR222DS-PD for Tmax T).
To make the PC (on which Ekip Connect is installed) communicate with the trip units, it is necessary to use a serial converter for converting from the physical level RS-485 (on the trip unit side) to the physical level through which you wish to connect to the PC (e.g.: RS-232, USB, Ethernet). The communication protocol to be used is Modbus RTU.

With Ekip Connect it is possible to:
1) carry out a check and a complete scanning of the communication network Modbus RS-485 in order to identify all connected devices and to detect any possible error of connection or of setting of the communication parameters (e.g.: address, baud rate, parity check)
2) interact in real time with the following devices:

Device

Circuit-breaker	Trip unit
SACE Tmax XT2-XT4	Ekip LSI + Ekip Com communication module Ekip LSIG + Ekip Com communication module Ekip M-LRIU + Ekip Com communication module Ekip E-LSIG + Ekip Com communication module
Tmax T4÷T6	PR222DS-PD PR223DS PR223EF
Tmax T7 - Emax X1	PR332/P + PR330/D-M communication module PR333/P + PR330/D-M communication module
New Emax E1÷E6	PR122/P + PR120/D-M communication module PR123/P + PR120/D-M communication module
Emax DC	PR122/DC + PR120/D-M communication module PR123/DC + PR120/D-M communication module
Emax E2/VF-E3/VF	PR122/VF + PR120/D-M communication module
Flex interface SD030DX	Thermal magnetic or basic electronic trip units (for further details see clause 4.5)

with the purpose of:
- reading the information (alarms, measures, parameters and state) present in the circuit-breakers;
- modifying the configuration and protection parameters (thresholds and trip times of the protections) set;
- sending commands (e.g.: opening and closing) to the circuit-breakers.

Ekip Connect is particularly useful for the commissioning, configuration, monitoring, maintenance and testing of the circuit-breakers equipped with Modbus communication interface.

4.8.1 Scanning of the system bus

Thanks to this function, the software carries out the automatic scanning of the Modbus RS-485 network and identifies all the devices connected to the bus.
At the end of the scanning operation, the devices found are displayed both in the Navigation area - through a node tree structure – as well as in the Main area.
The devices connected to the network can be viewed in the Main area (see Figure 30), with their main communication parameters and any warning about potential problems or configuration errors detected in the scanning process (e.g.: two devices with different baud rate or two devices with the same Slave Address), for a complete diagnosis of the communication network.
Ekip Connect signals in the Main area also the presence of non-ABB devices able to communicate via Modbus RTU protocol, and their relevant communication parameters.

Figure 31 shows an example of the node tree structure of the Navigation area, generated after a scanning of the communication network.
The main node, at the first level, shows the Modbus network to which the different devices are connected; the nodes at the second level indicate the devices (e.g.: the trip units) connected to the communication network; the nodes at the third level indicate the information, the data and the alarms put at disposal by the selected trip unit (one node of the second Level).

Detailed information can be viewed in the Main area and in particular:
- by selecting the node at the first level, a summary of all the detected devices connected to the Modbus network and of their relevant communication parameters is displayed;
- by selecting one of the node at the second level, it is possible to view a summary of the main communication parameters (e.g.: COM port, slave address, baud rate) of the selected device (e.g.: a trip unit) and of any possible problem which has occurred during scanning operations;
- by selecting the nodes of the third level it is possible to view detailed information and data of the trip unit, to modify the communication parameters and the settings of the protections and to send commands to the circuit-breaker (see clause 4.8.2).

Figure 30: Screen shot of the Ekip Connect with the Navigation area and the Main area generated at the end of one scanning operation

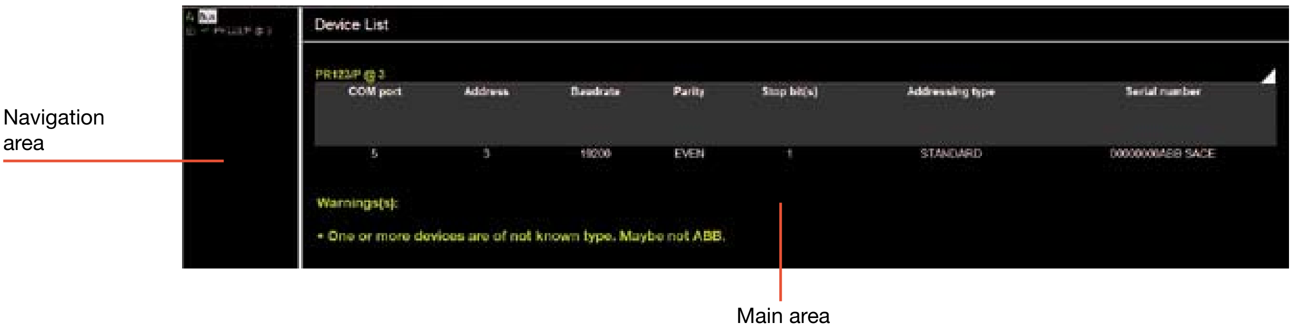
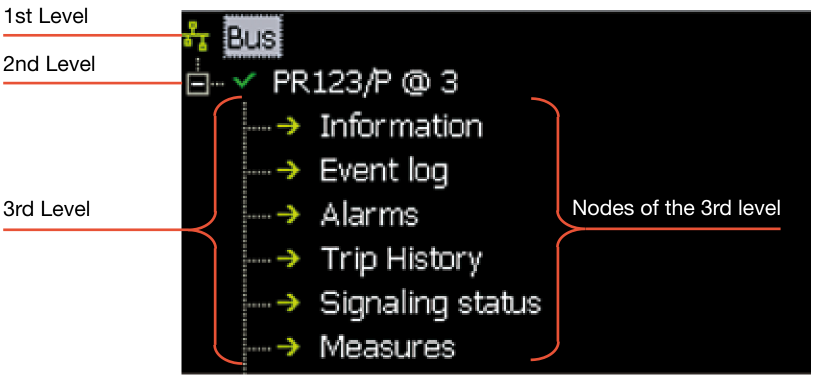


Figure 31: Tree structure of the Navigation area



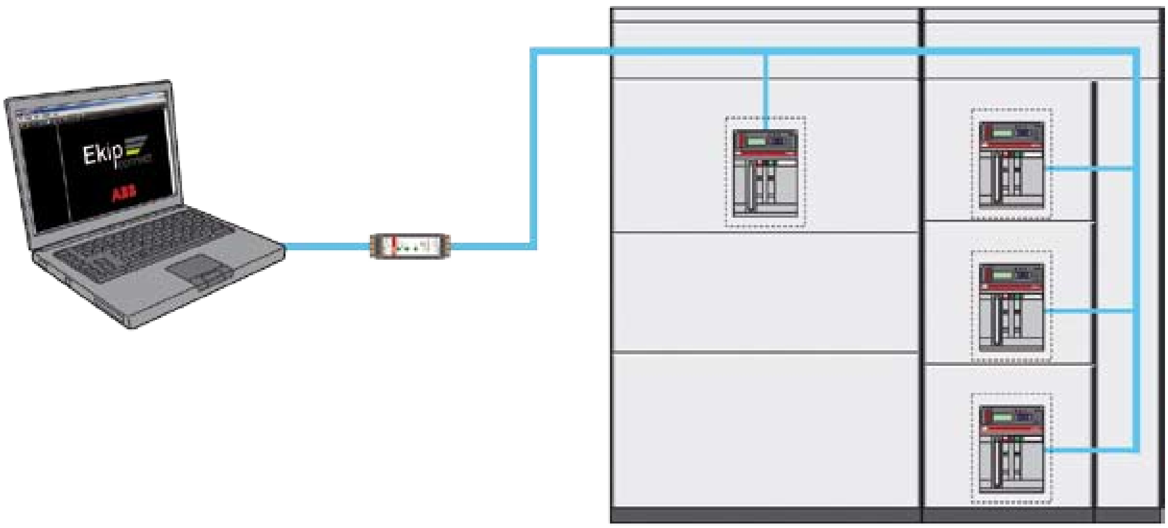
During the testing of a switchboard equipped with devices which communicate via Modbus and designed to be installed in a plant provided with a supervision system, the scanning of the system bus is particularly useful. In fact, this control operation allows wiring anomalies of the devices connected to the Modbus network, setting errors of the communication parameters (e.g.: baud rate, parity, number of stop bits, etc.) or configuration errors of the connected devices (e.g.: logical address) to be detected; thus there is the possibility of correcting them at a stage when the switchboard is not in service yet.
Thanks to these verifications, in case of communication anomalies of the supervision systems of the plant during commissioning of the switchboard, such problems cannot be put down to the circuit-breakers installed in the switchboard.

4.8.2 Communication with a single device

Ekip connect offers some graphic displays through which it is possible to interact with the electronic trip units.
The windows are displayed in the Main area when a node (of the 3rd level) is selected from the Navigation area.
Some windows are associated with each trip unit and they enable you to:
- read the measurements on the circuit-breaker and on the protection trip unit;
- know the circuit-breaker state (e.g.: open/closed, connected/insulated);
- display the protection alarms;
- read the electrical quantities measured in real time (e.g.: currents, voltages, power, energy);
- display the parameters of the protection functions associated with the trip unit;
- display the history data relevant to the last trips of the trip unit;
- display the event history and measures stored by the trip unit.

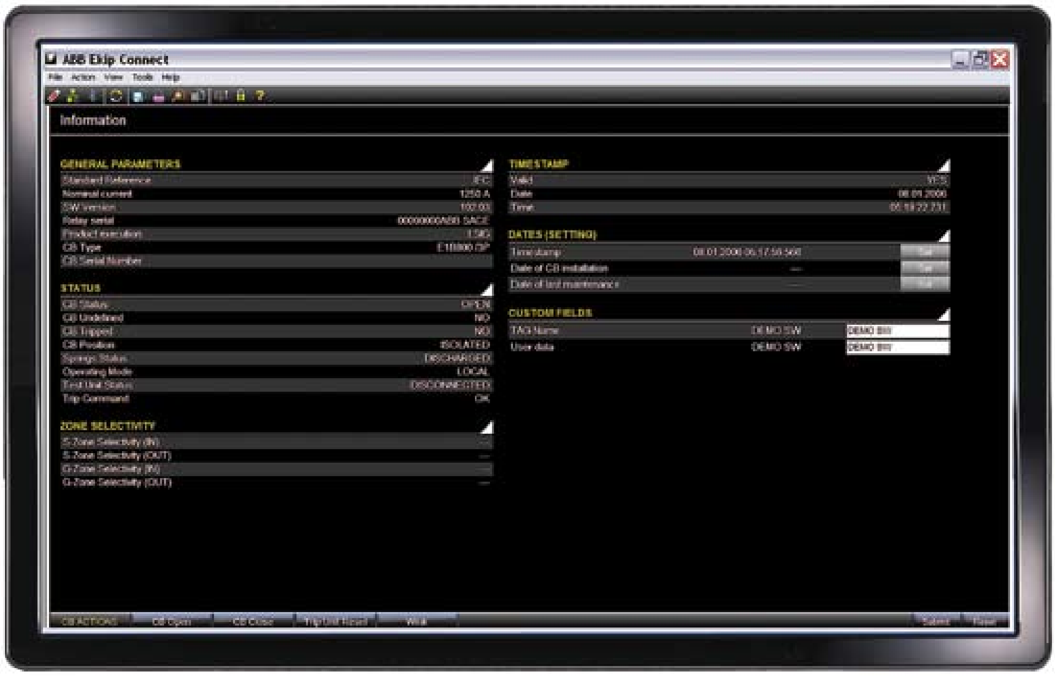
Moreover, through the graphic displays, it is possible:
- send opening and closing commands to the circuit-breaker;
- send CB reset command (this command, which is available for the moulded-case circuit-breakers with motor operator, switches the circuit-breaker from “tripped” to “open” position);
- send trip unit reset commands (to reset the signals associated with the latest trip of the trip unit);
- set the thresholds and trip times of the protections associated with the trip unit;
- display the time-current curves of the protection devices;
- send the wink commands which activate the winking of the display or the blinking of a LED of the trip unit; this to make easier the identification of the circuit-breaker installed in the plant.

The quantity and type of information which can be viewed through the graphic displays vary according to the type of trip unit involved.
Here are shown some of the available windows.



- Information

In this window it is possible to read the general information about the device (e.g.: standard of reference, rated current of the circuit-breaker, software version, type of circuit-breaker, information on the circuit-breaker state) and to send opening/closing, trip unit reset commands and the wink command. To send these commands it is necessary to insert a password. When the device is set in local mode, the commands may not be operated.



- Measures

This window shows the measures acquired in real time by the trip unit; the information and the type of electrical quantities which can be displayed vary according to the type of trip unit involved (see Annex A).

- Measures history

With the trip units type PR122/P and PR123/P for Emax and PR332/P and PR333/P for Tmax T7 and Emax X1 it is possible to view the values of the following electrical quantities:
- the total active power (medium and maximum value)
- the phase at the maximum current
- the maximum current value (RMS value)
- the phase at the minimum and maximum voltage
- the phase at the minimum voltage and the minimum voltage value
- the total reactive power (medium and maximum value)
- the total apparent power (medium and maximum value)

measured in the last 24 periods of time which can be set at intervals from 5 minutes (storage of the last 2 hours) 120 minutes (storage of the last 48 hours).

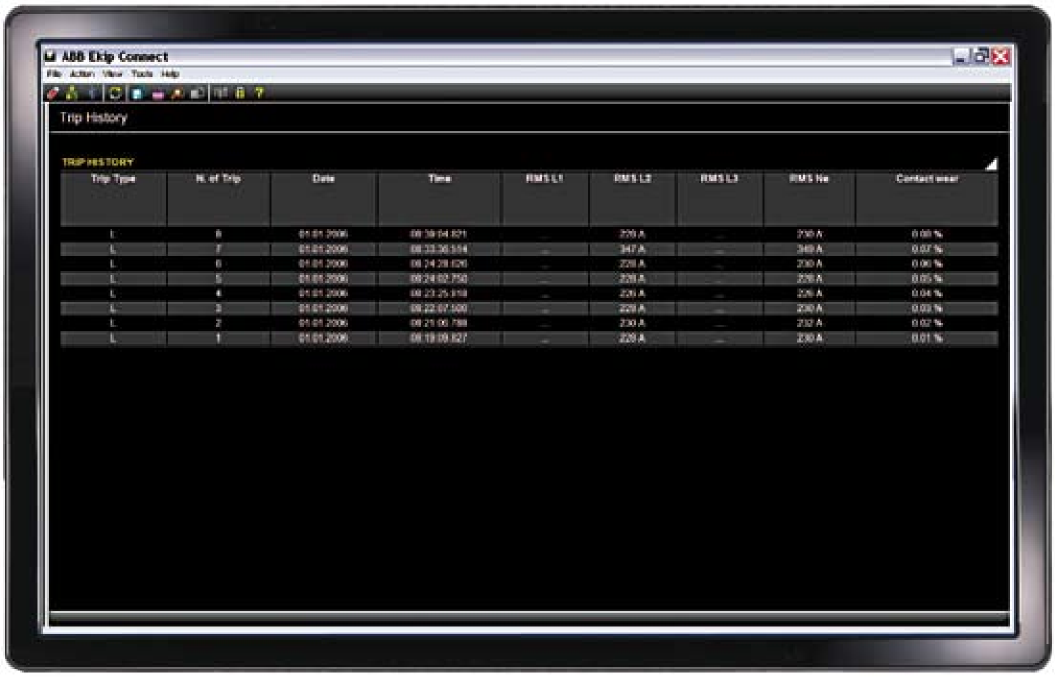
With SACE Tmax XT4 circuit-breakers, thanks to the electronic trip units Ekip E-LSIG, it is possible to view the maximum and minimum values which the following quantities have reached up to that moment:
- phase currents (IL1 maximum value - IL2 maximum value -IL3 maximum value, IL1 minimum value -IL2 minimum value - IL3 minimum value);
- current in the neutral (INe maximum value, INe minimum value) (in the presence of the neutral);
- line-to-line voltages (V12 maximum value - V23 maximum value - V31 maximum value, V12 minimum value - V23 minimum value - V31 minimum value);
- line-to-neutral voltages (V1N maximum value - V2N maximum value - V3N maximum value, V1N minimum value - V2N minimum value - V3N minimum value) (in the presence of the neutral);
- frequency (maximum value, minimum value);
- total active power (Ptot maximum value, Ptot minimum value) and, in the presence of the neutral, the active power on the three lines (P1 maximum value, P2 maximum value, P3 maximum value, P1 minimum value, P2 minimum value, P3 minimum value);
- total reactive power (Qtot maximum value, Qtot minimum value) and, in the presence of the neutral, the reactive power on the three lines (Q1 maximum value, Q2 maximum value, Q3 maximum value, Q1 minimum value, Q2 minimum value, Q3 minimum value);
- total apparent power (Stot maximum value, Stot minimum value) and, in the presence of the neutral, the apparent power on the three lines (S1 maximum value, S2 maximum value, S3 maximum value, S1 minimum value, S2 minimum value, S3 minimum value).

- Alarms

This window displays the alarm entries of the protections associated with the trip unit and the diagnostic alarms associated with the circuit-breaker (e.g.: trip coil disconnected or failed, current sensors disconnected). The quantity and type of alarms which can be displayed vary according to the type of trip unit with which interaction occurs.

- Trip

This window offers the possibility of obtaining more information about the cause of tripping (e.g.: type of protection tripped, values of the interrupted currents, time and date of tripping, contact wear). Some trip units allow access also to the information associated with the previous trips. The quantity and type of information which can be displayed vary according to the type of trip unit with which interaction occurs.

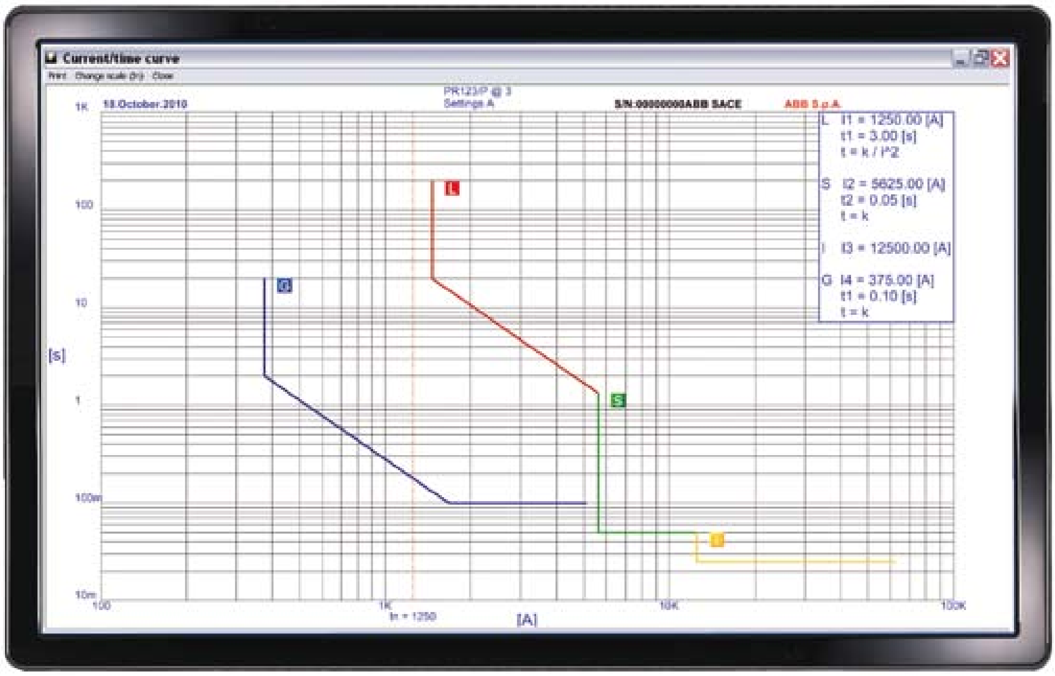


- Settings

Through this window it is possible to view and set the values (thresholds and trip times) of the protection functions of the trip unit. The protection functions which can be viewed vary according to the type of trip unit with which interaction occurs.

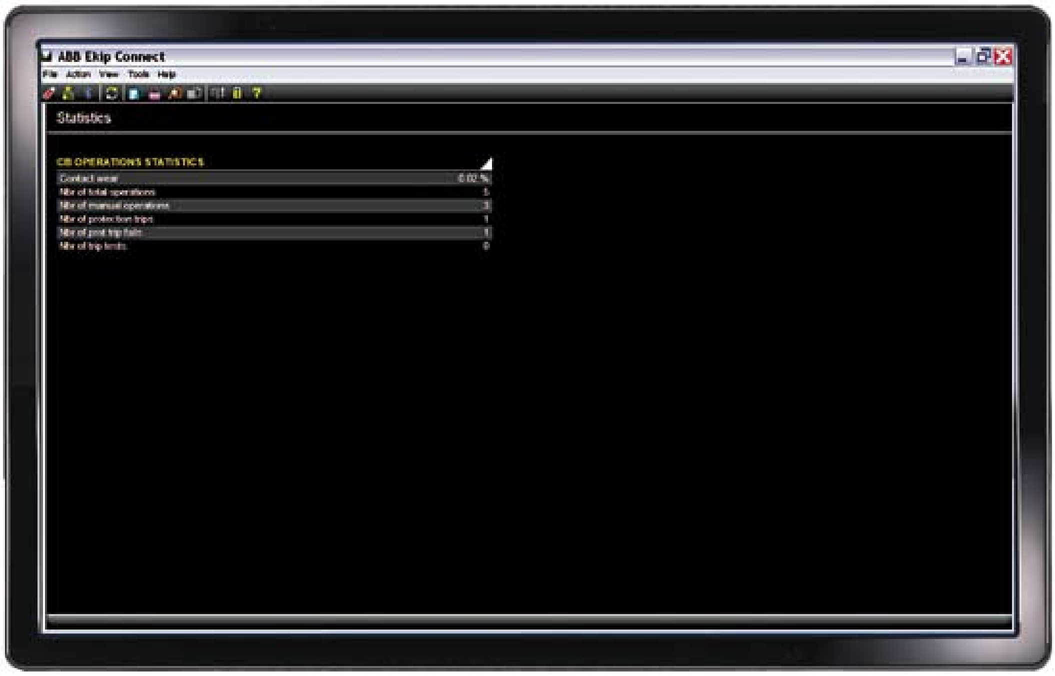
- Time-current curves

Thanks to this function it is possible to view the trend of the time-current curves set for the main protection functions (L, S, I and G).



- Statistics of the operations performed by the circuit-breaker

In this window it is possible to display: the percentage of contact wear, the total number of operations, the number of manual operations, the number of protection tripping, the number of failed trips and the number of test trips, carried out by the circuit-breaker. The data which can be viewed vary according to the type of trip unit with which interaction occurs.



NOTE: For further information about the use of the software Ekip Connect and about the functions put at disposal see the User Manual “Instructions for use for communication software EKIP Connect compatible with low voltage circuit-breakers by ABB SACE” (document code: 1SDH000891R0002).

4.9 Example of product selection for supervision and remote control

Consider a LV distribution plant with supervision of the type shown in Figure 32, the supervision system uses a bus network with Modbus protocol RTU on RS-485.
At the control level there is a PC on which a supervision system is installed; for the connection of the PC to the bus a serial converter RS-232/RS-485 is used.
The personal computer operates as SCADA acquiring, processing and storing the data sent from all the circuit-breakers.
The field level consists of the protection circuit-breakers type SACE Tmax XT4, Tmax T4 and Emax E1, equipped with the following electronic microprocessor-based trip units, respectively:

- Ekip E-LSIG (QF4, QF5);
- PR223DS (QF6 and QF7);
- PR123/P (QF2 and QF3).

Choice of products and accessories for supervision
For the supervision of the plant the following devices are needed:

- *Emax E1 air circuit-breakers (QF2 and QF3) equipped with:*
  1) PR123/P electronic trip unit;
  2) PR120/D-M communcation module;
  3) PR120/V measuring module (mounted by default on PR123/P trip unit);
  4) auxiliary power supply Vaux (see Annex B).

- *SACE Tmax XT4 moulded-case circuit-breakers (QF4, QF5) equipped with:*
  1) Ekip E- LSIG electronic trip unit;
  2) Ekip Com communication module (see Annex C);
  3) auxiliary supply voltage Vaux (see Annex B).

As it can be noticed, with Ekip-E LSIG trip unit for SACE Tmax XT4 it is possible to measure voltages and energy without having to use external measuring modules.

- *Tmax T4 moulded-case circuit-breakers (QF6 and QF7) equipped with:*
  1) PR223DS electronic trip unit;
  2) X3 rear connector (see Annexes B and C);
  3) VM210 measuring module (see Annex D);
  4) X4 rear connector (see Annex D);
  5) auxiliary contacts in electronic version AUX-E (see Annex E);
  6) auxiliary supply voltage Vaux (see Annex B)

Choice of products and accessories for remote control

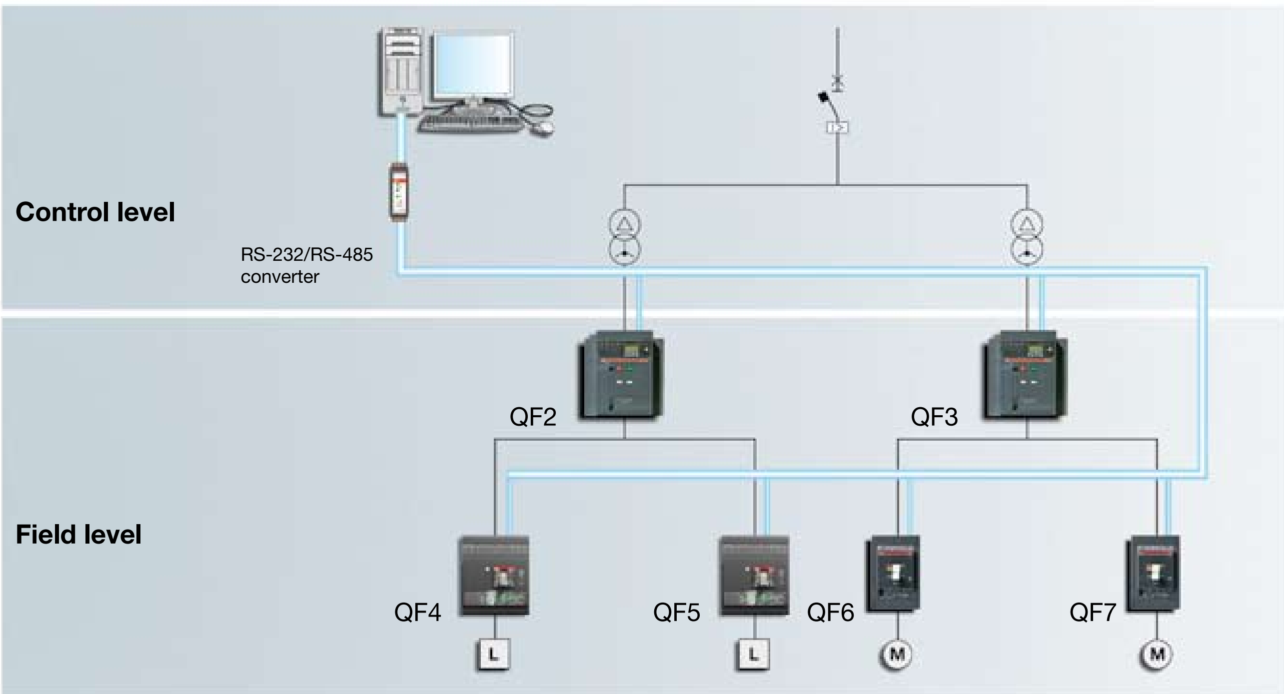
To perform circuit-breaker remote control the following accessories are necessary:

- *For Emax E1 air circuit-breakers (QF2 and QF3):*
  1) shunt opening release (YO)
  2) shunt closing release (YC)
  3) geared motor for the automatic charging of the closing springs (M)

- *Moulded-case circuit-breakers SACE Tmax XT4 (QF4 and QF5)*
  1) motor operator with MOE-E module (see Annex F).

- *Moulded-case circuit-breakers Tmax T4 (QF6 and QF7)*
  1) motor operator with MOE-E module (see Annex E);
  2) AUX-E auxiliary contacts in electronic version (provided by default with MOE-E).

Figure 32: Supervision and control system of a LV distribution plant



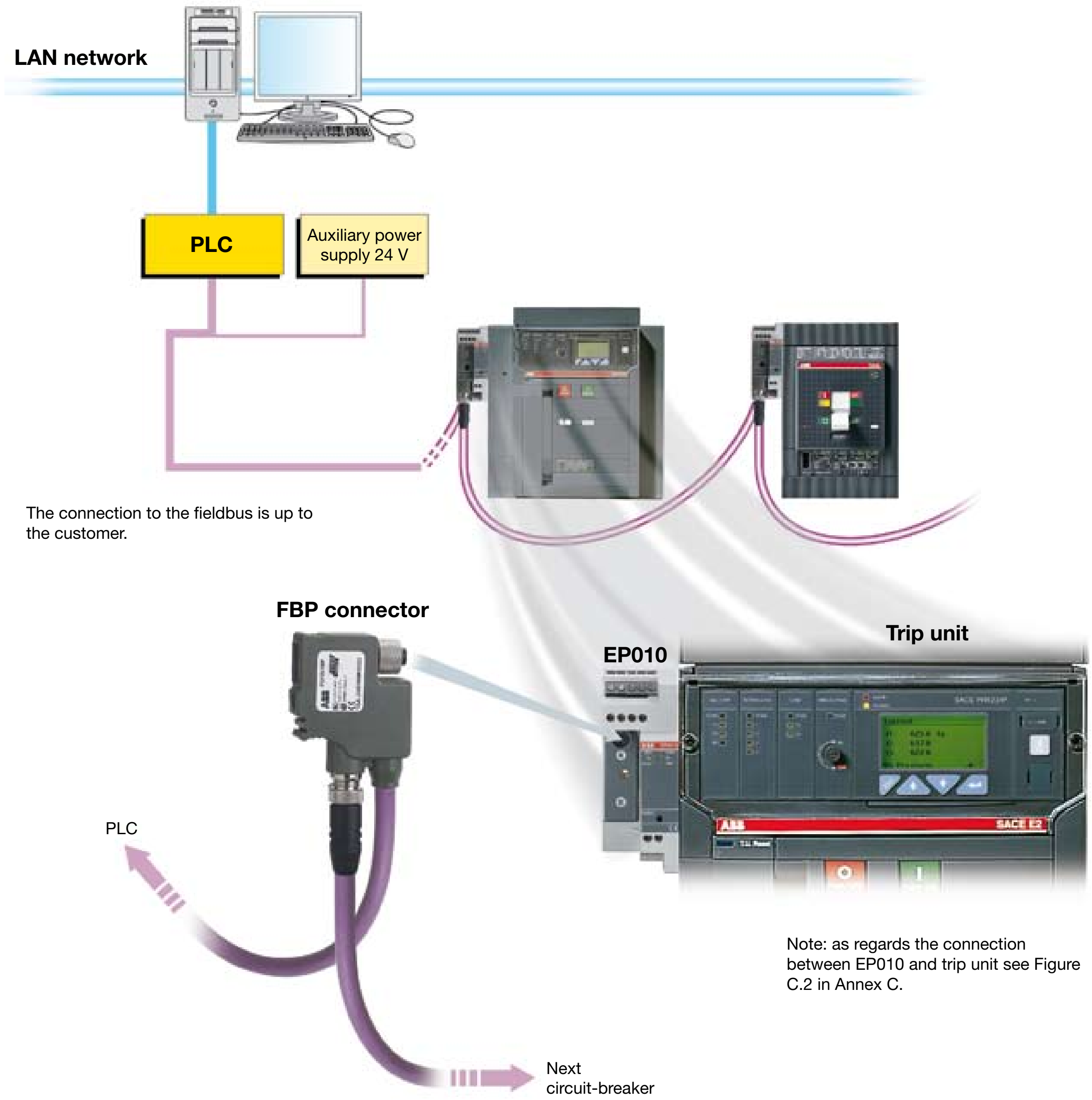
4.10 ABB circuit-breakers in Profibus DP and DeviceNet fieldbus

EP010 fieldbus interface unit allows the integration of ABB SACE circuit-breakers into communication systems with Profibus DP or DeviceNet protocol.
EP010 establishes, together with the ABB intelligent connector type FBP FieldBusPlug, the connection between a fieldbus and the trip unit connected to its Modbus port.
In particular, EP010 unit operates as gateway for the communication between the FBP connector and the electronic trip unit.

As a consequence, with each EP010 unit, the suitable connector FBP FieldBusPlug must be used; in particular, for each circuit-breaker to be integrated into the fieldbus the following items are needed:
- EP010 unit + one PDP22-FBP connector (for fieldbus Profibus DP);

or
- EP010 unit + one DNP21-FBP connector (for fieldbus DeviceNet).

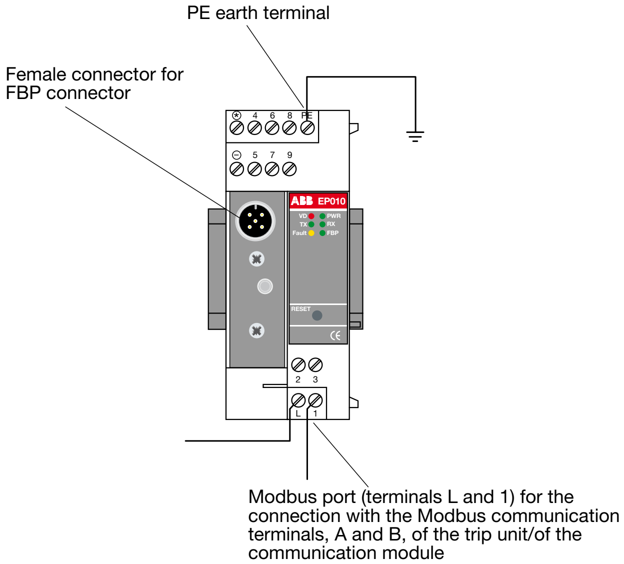
The connection of the circuit-breakers to the fieldbus is achieved as shown in the figure.



The same communication system is used with other ABB products, such as: PLC, motor starters, universal motor controllers, softstarters and position sensors.

Therefore it is possible to use circuit-breakers in industrial automation systems for the most different applications, thus combining the control of a process with the control of the electrical distribution plant which supplies it.

Connections to EP010 unit



- As regards the communication between the electronic trip unit and EP010 unit, the connection between the Modbus terminals - A and B – of the trip unit/of the communication module and the Modbus terminals - L (left) and 1 (right) – of EP010, must be made as shown in the following table:

Modbus terminals (EP010)	Modbus communication terminals of the trip unit/of the communication module
L (left)	A (W1)
1 (right)	B (W2)

- The Modbus cable which connects EP010 to the trip unit shall have the maximum length of 1 m.

- The PE terminal of EP010 unit must be earthed.

- The power supply at 24 V dc for EP010 unit is delivered through the FBP connector, which provides also bus communication.
  The trip unit connected to EP010 shall be supplied by an auxiliary voltage Vaux at 24 V dc (for the electrical characteristics see Annex B).

NOTE: For further information see the following documents:
- Modbus/FBP Interface - User and Operator Manual (document code: 1SDH000510R0001);
- Modbus/FBP interface Annex for PR223EF User and Operator Manual (document code: 1SDH000663R0001).

4.10.1 Emax air circuit-breakers E1÷E6, Emax X1 air circuit-breakers and Tmax T7/T7M moulded-case circuit-breakers

Profibus DP and DeviceNet: supervision and remote control

Emax air circuit-breakers equipped with the electronic trip units PR122/P or PR123/P are connected to EP010 unit through PR120/D-M communication module as shown in Annex C.

Emax X1 air circuit-breakers equipped with PR332/P or PR333/P electronic trip units and Tmax T7 or T7M moulded-case circuit-breakers equipped with PR332/P trip unit are connected to EP010 through PR330/D-M communication module as shown in Annex C.

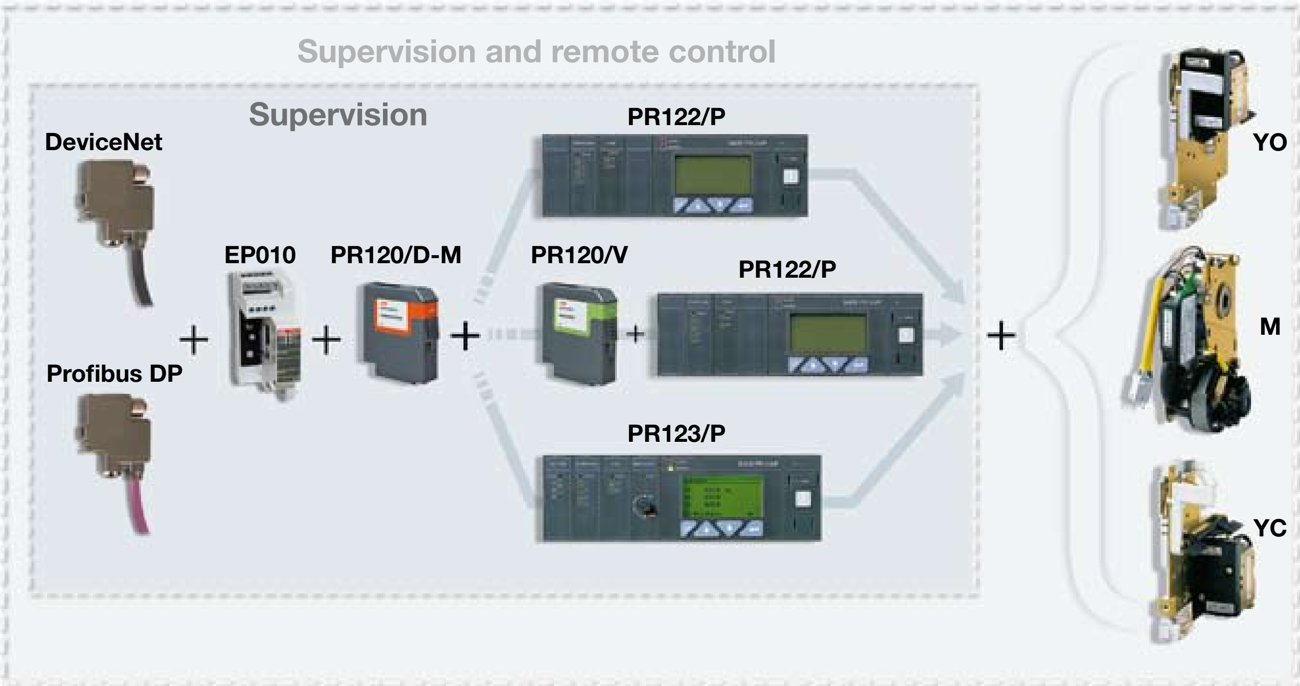
For the air circuit-breakers type Emax E1÷E6 and Emax X1 and for Tmax T7/T7M moulded-case circuit-breakers, there is only one version of EP010 unit which is compatible with all the trip units PR122/P, PR123/P, PR332/P and PR333/P.

For information about the measures, data and alarms placed at disposal by the trip units type PR122/P, PR123/P, PR332/P and PR333/P in the following configurations see Table A.4 of Annex A.

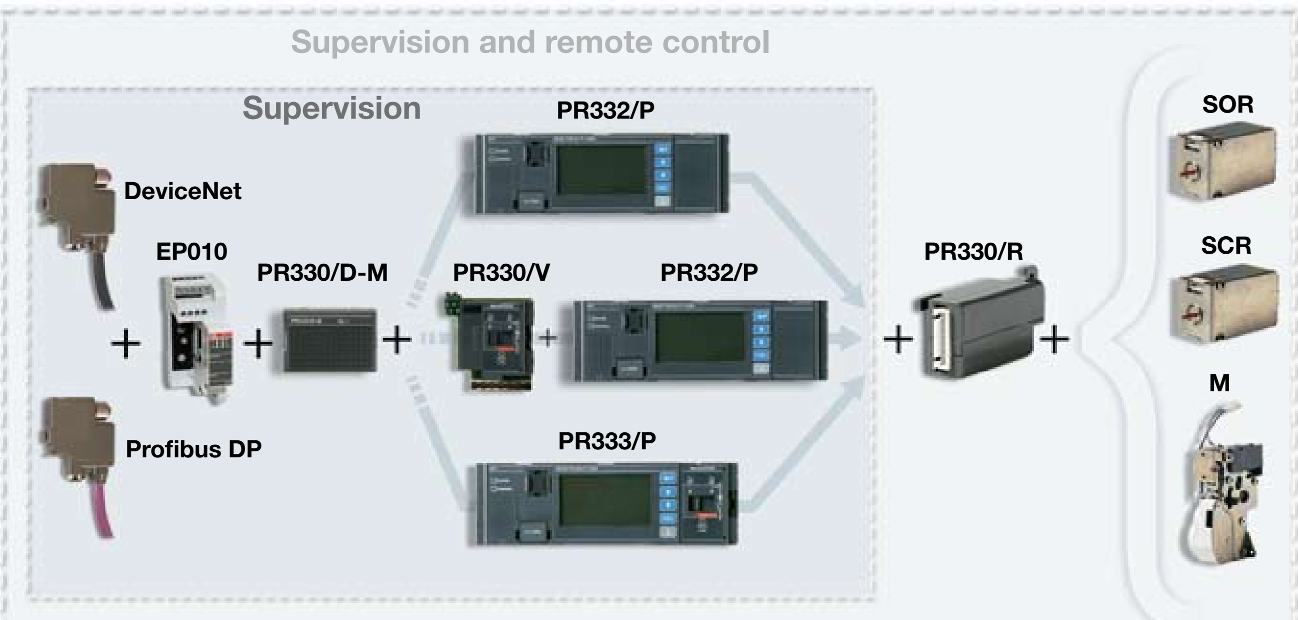
As regards the remote control operations which can be performed on the circuit-breaker see Table A.4 of Annex A, under the entry “Commands”.

All the commands from remote (via bus) can be blocked by setting the trip unit to local mode.

Emax E1÷ E6 (PR122/P-PR123/P electronic trip units)



Emax X1 (PR332/P-PR333/P electronic trip units) and Tmax T7/T7M (PR332/P electronic trip units)



For remote control with Tmax T7 the motorizable version type T7M is needed.

4.10.2 Moulded-case circuit-breakers Tmax T4-T5-T6

Profibus DP and DeviceNet: supervision and remote control

The moulded-case circuit-breakers type Tmax T4, T5 and T6 with PR222DS/PD and PR223EF electronic trip units are connected to EP010 unit through X3 rear connector as shown in Annex C.

For Tmax T moulded-case circuit-breakers there are two different versions of the unit EP010, each of them compatible with the suitable trip unit.

In particular:

- with PR222DS/PD trip unit, the EP010 identified by the product code 1SDA059469R1 is used (see the Technical Catalogue Tmax. T Generation – Low voltage moulded-case circuit-breakers up to 1600 A).
- with PR223EF trip unit, the EP010 identified by the product code 1SDA064515R1 is used (see the Technical Catalogue Tmax. T Generation – Low voltage moulded-case circuit-breakers up to 1600 A).

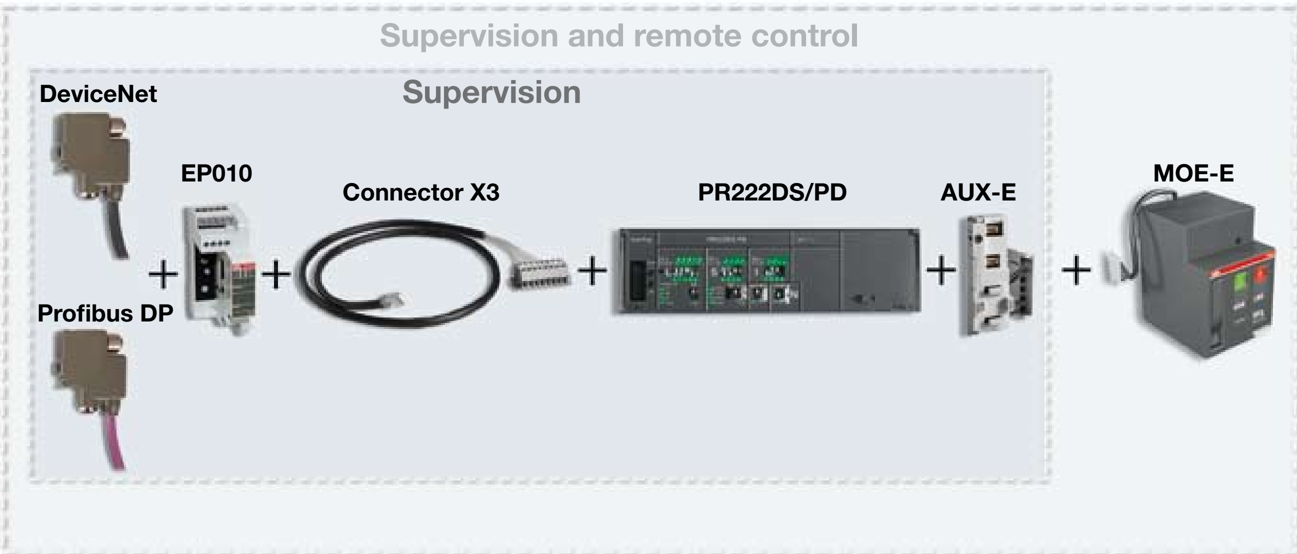
To perform the remote control and the mechanical implementation of the remote opening and closing commands, Tmax T4, T5 and T6 moulded-case circuit-breakers must be fitted with MOE-E motor operator with electronic interface and AUX-E auxiliary contacts in electronic version.

For information about the measures, data and alarms placed at disposal by the trip units type PR222DS/PD and PR223EF in the following configurations see Table A.5 of Annex A.

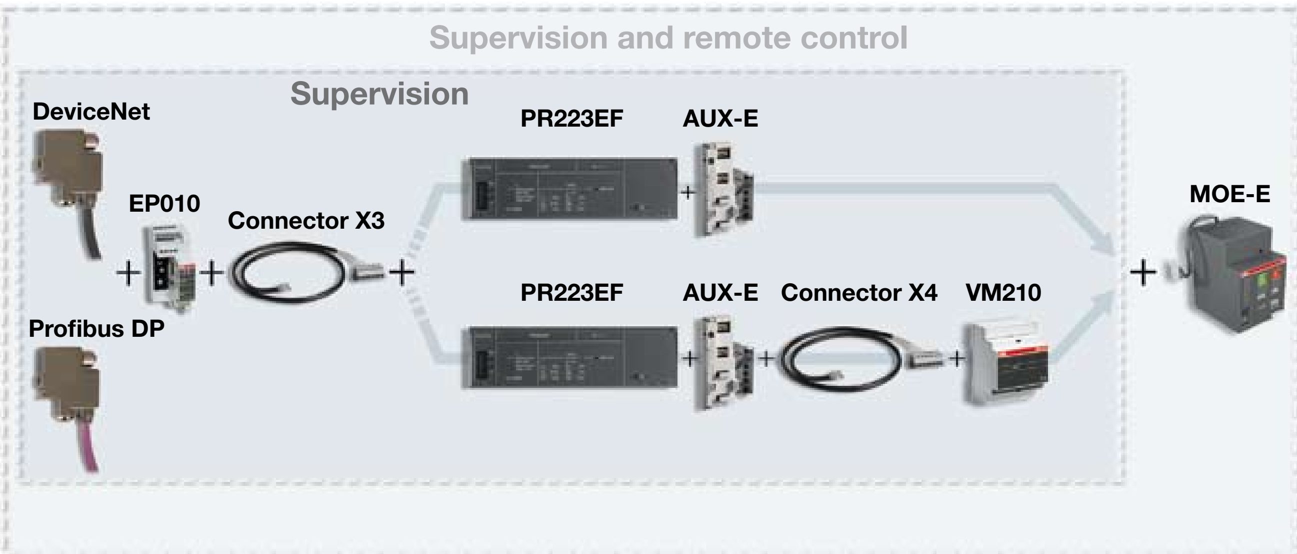
As regards the remote control operations which can be performed on the circuit-breaker see Table A.5 of Annex A, under the entry "Commands".

All the commands from remote (via bus) can be blocked by setting the trip unit to local mode.

- PR222DS/PD electronic trip unit



- PR223EF electronic trip unit

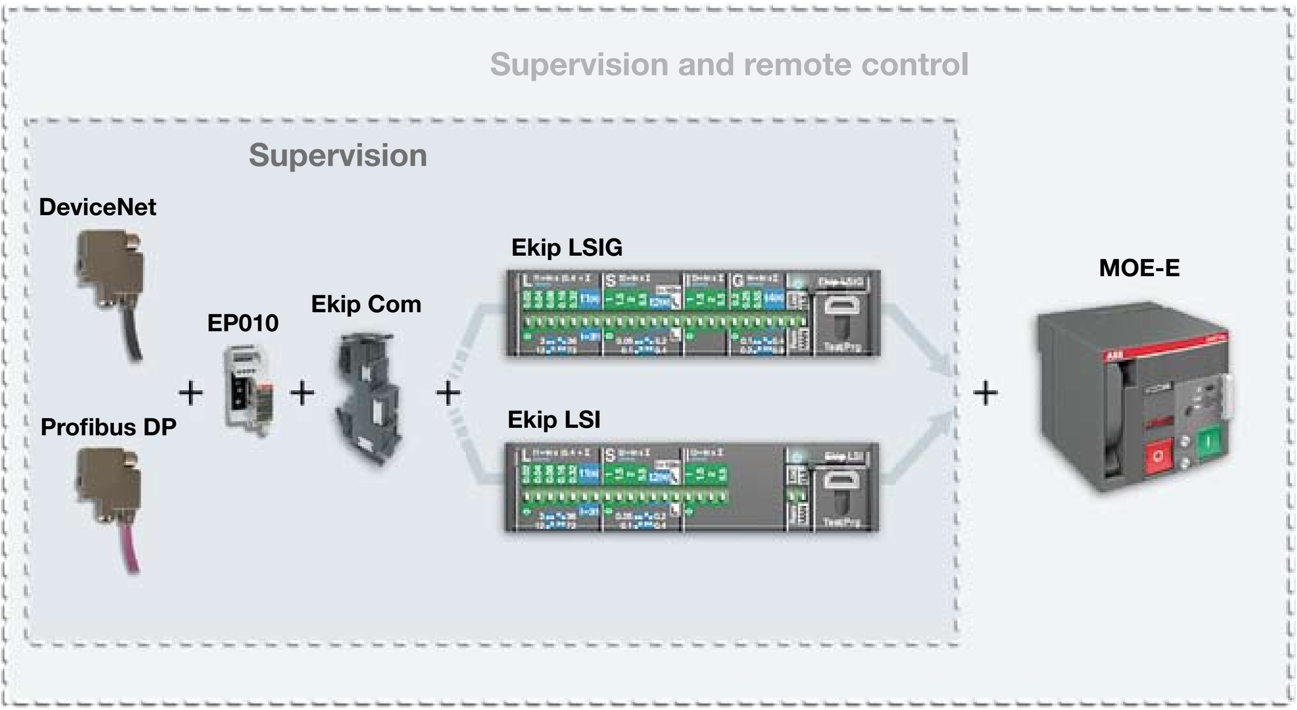


4.10.3 Moulded-case circuit-breakers SACE Tmax XT2-XT4

Profibus DP and DeviceNet: supervision and remote control
SACE Tmax XT2 and XT4 moulded-case circuit-breakers, equipped with the electronic trip units type Ekip LSI and Ekip LSIG are connected to EP010 unit through Ekip Com communication module.
For SACE Tmax XT2 and XT4 moulded-case circuit-breakers, there is only one version of EP010 unit, which is compatible with both the trip units Ekip LSI and Ekip LSIG.
To carry out from remote the opening/closing and reset commands, SACE Tmax XT2 and XT4 moulded-case circuit-breakers must be equipped with the motor operator with electronic interface MOE-E (see Annex F).
For information about the measures, data and alarms placed at disposal by the electronic trip units Ekip LSI and Ekip LSIG in the following configurations see Table A.6 of Annex A.

As regards the remote control operations which can be performed on the circuit-breaker see Table A.6 of Annex A, under the entry "Commands".
All the commands from remote (via bus) can be blocked by setting the trip unit to local mode.

- Ekip LSI and Ekip LSIG electronic trip units



NOTE: For more detailed information on the dialogue functions and on the characteristics of the products described in this clause reference has to be made to the relevant catalogues and product technical manuals.

4.11 Measuring instruments

The measuring instruments for the installation inside MV and LV primary and secondary industrial distribution panels represent an ideal enhancement of the ABB offer through which the panel can be configured as function-integrated system.
ABB offer of digital instruments provided with communication function includes:
- DMTME multimeters both in modular version as well as in front panel version;
- ANR network analysers for an accurate control of network quality;
- MID certified energy meters for monitoring of the energy consumption of single loads and of the plant;
- TMD temperature control units for the control of temperatures on the windings of the power transformers.

4.11.1 DMTME multimeters

The multimeters of the DMTME series are digital multimeters which enable the main electrical quantities to be measured (TRMS values) in 230/400 V a.c. three-phase networks, the maximum, minimum and average values of the main electrical parameters to be stored and the active and reactive energy to be metered.
The multimeters of the DMTME series enable the same instrument to be used as a voltmeter, ammeter, power-factor meter, wattmeter, varmeter, frequency meter, active and reactive energy meter and hour meter, thus permitting significant savings because both the size inside the panels as well as the wiring time can be reduced.
In the version DMTME-I-485 the multimeter is provided with two digital outputs, which can be programmed as alarm thresholds and pulse outputs for remote control of energy consumption, and with a serial port RS485.
From the serial port RS485, several multimeters and other digital instruments can be connected to a communication network via Modbus RTU protocol (up to 32 measuring instruments in addition to the master can be connected).

The main technical characteristics of these devices are summarized in the following table:

Rated voltage		[V rms] 230 +15% - 10% DMTME-72 and DMTME-96
		[V rms] 240 +15% - 10% DMTME-72 and DMTME-96
		[V rms] 400 +10% - 10% DMTME-72
		[V rms] 400 +10% - 10% DMTME-72
		[V rms] 115 +15% - 10% DMTME-96
		[V rms] 120 +15% - 10% DMTME-96
Frequency		[Hz] 45…65
Power consumption		[VA] < 6
Measurement accuracy:	Voltage	± 0.5% F.S. ± 1 digit in the range
	Current	± 0.5% F.S. ± 1 digit in the range
	Active power	±1% ± 0.1% F.S. from cosφ= 0.3 to cosφ= -0.3
	Frequency	± 0.2% ± 0.1Hz from 40 to 99.9 Hz
		± 0.2% ± 1Hz from 100 to 500 Hz
Energy metering	Maximum metered value for single phase	4294.9 MWh (Mvarh) with kA = KV = 1
	Maximum metered value for three phase	4294.9 MWh (Mvarh) with KA = KV = 1
	Accuracy	Class index 1
Communication parameters:	Protocol	Modbus RTU
	Physical interface	RS-485
	Baud rate	4800 bps, 9600 bps, 19200 bps
	Parity	Odd, Even, None
	Stop bit	0.1
	Address	1... 247

NOTE: For more detailed information, see the technical catalogue “System pro *M* compact”

4.11.2 ANR network analysers

When more advanced analysis functions are required, to enrich the range of ABB front-panel instruments ANR network analysers allow network parameters, alarms and information about other devices' state to be measured and recorded; it also allows addressing the data to remote supervision and control systems.
The software SW01 - which they are provided with – represents a first-hand tool for the remote visualization of the measures and for recording of the latter and pre-programmed alarms directly on the user's PC.
The performances are top-level:
- measurement and analysis of more than 60 electrical parameters;
- voltage and current measures as true and effective value ("true RMS") with accuracy class index 0.5;
- remote communication of measures according to different modalities: programmable analogue outputs, digital outputs for remote control, programmable as threshold alarms or pulse outputs; acquisition of the state of other devices in the panel; communication protocols such as: Modbus RTU, Profibus DP, Ethernet Modbus TCP/IP.

Their use permits efficient monitoring of the quality of the energy in both single-phase and three-phase distribution networks through the instantaneous and historical analyses of voltage variations, supply interruptions, and of harmonics up to the 31st order and through the display of the wave shapes of voltage and current. Their use allows also an optimization of the energy costs through an accurate historical analysis of energy consumption in four tariffs.

The main technical characteristics of the ANR network analysers are summarized by the following table:

Voltage (TRMS)	Direct measurement [V]	10 - 600
	Ratio transformer range kTV [V]	0.01 – 5000.00
	Max overvoltage [V]	750, above this value it is necessary to use a voltage transformer
Consumption [VA]		0,2
Input resistor [MΩ]		> 2
Current (TRMS)	3 isolated inputs [A] Minimum current value [mA]	0,01 – 5 10
	Consumption [VA]	0,2
	Max overcurrent [A]	10 (100 A for 1 second)
	Ratio transformer range kCT	0,01 - 5000,00
THD	Voltage and current	Up to the 31st harmonic
Frequency [Hz]		30-500
Accuracy class	Current [%]	< 0.5 (EN 61036)
	Voltage [%]	< 0.5
	Power [%]	< 1
	Power factor [%]	< 1
	Active energy [%]	< 1 (IEC 62052-11)
	Reactive energy [%]	2 (IEC 62053-23)
Communication parameters:	Protocol	Modbus RTU
	Physical interface	RS-485
	Baud rate	4800 bps, 9600 bps, 19200 bps
	Parity	Odd, Even, None
	Stop bit	0,.1
	Address	1... 247

NOTE: For more detailed information see the technical catalogue "System pro *M* compact"

4.11.3 Temperature control units

They are used to monitor the temperature levels and the ventilation functions of electric machines, transformers, motors, etc. Preventive control of temperature enables malfunctions and overloading to be avoided.
Four PT100 type sensors are used to measure temperatures. For each measurement channel two alarm levels (alarm-trip) can be set; they switch two output relays for remote signaling if a critical temperature level has been reached.
In addition, the units enable the maximum values to be stored, each intervention to be stored and ventilation inside the panel to be controlled. The temperature values and the alarm state can be remotely transmitted through the serial output RS845 with Modbus RTU protocol.

The figure below shows the front-panel temperature control unit TMD-T4/96.

The main technical characteristics of TMD-T4/96 temperature control units are summarized in the following table:

Auxiliary supply [V]		20..250 ± 15%
Power consumption [VA]		4
Measuring inputs		PT100 RTD
Measuring range [°C]		0…+220 ± 2 °C
Trip delay – hysteresis		5/2 s/°C
Measurement display		7 segments LED
Outputs		1 to 12 V d.c., 3 NO-CO-NC relays, 8 A resistive load
Outlet functions		alarm, trip, ventilation, self-diagnosis
Programmable functions		ALARM, TRIP, HOLD, FAN, T. MAX
Communication parameters:	Protocol	Modbus RTU
	Physical interface	RS-485
	Baud rate	2400 bps, 4800 bps, 9600 bps, 19200 bps
	Parity	Odd, Even, None
	Address	1... 247
Standards		IEC EN 50081-2, IEC EN 50082-2
		IEC 14.1, IEC EN 60255

NOTE: For more detailed information see the technical catalogue “System pro M compact”

4.11.4 Electronic energy meters

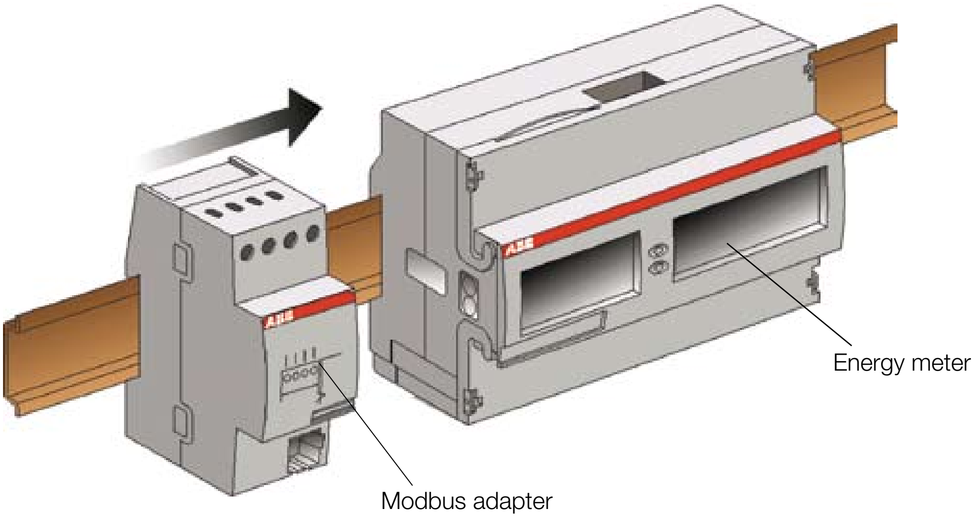
The wide range of ABB modular energy meters for measuring energy is shown in the table below. For a description of the specific technical characteristics of every single device, reference has to be made to the catalogue “System pro M compact”.
The energy meters can be profitably used in both residential/tertiary and industrial environments.
ABB meters are approved and certified in compliance with MID European Directive (Measuring Instruments Directive) and can be installed in environments where energy must be measured for fiscal purposes.

A typical example of the first case is offered by shopping centers where local energy consumption can be measured, a record of the history of consumption can be created, the building can be managed remotely and integrated in a supervision system provided with Modbus RTU protocol. Meters are offered with inbuilt communication (EQ meters Ax range) or with a separate communication adapter via the IR interface.

	EQ meters C11	ODINsingle	DELTAsingle	EQ meters A41	EQ meters A42
Overall dimensions	1 DIN module	2 DIN modules	4 DIN modules	4 DIN modules	4 DIN modules
Display	LCD	Backlit LCD	LCD	Backlit Pixel (LCD)	
Operating voltage	230 V AC	230 V AC	230 V AC	57-288 V AC	
Frequency	50/60 Hz				50/60/16.7 Hz
Max current	40 A	65 A	80 A	80 A	6 A
CTVT connected	-	-	-	-	CTVT

NOTE: For more detailed information see the technical catalogue “System pro M compact”

The figure below shows the coupling between energy meter and Modbus adapter



NOTE: For more detailed information see the technical catalogue “System pro M compact”





ODIN Meter	DELTAplus	DELTAmax	EQ meters A43	EQ meters A44
6 DIN modules	7 DIN modules	7 DIN modules	7 DIN modules	7 DIN modules
LCD	LCD	LCD	Backlit Pixel (LCD)	
230/400 V AC	57/100...288/500 V AC		57/100...288/500 V AC	100/173...400/690 V AC
50/60 Hz				
65, 10 A	80, 6 A			
CT	CTVT	CTVT	-	CTVT

4.12 Serial converter RS485/RS232

The multifunction serial converter CUS is used in all cases in which it is necessary to convert or manage the serial lines EIA -232 (RS-232), EIA-485 (RS-485) and EIA-422 (RS-422).
The communication links between devices using these types of buses (such as for example PLCs, measuring and control instruments, peripherals and computers running specific software applications, etc.) often requires the type of serial line to be converted, the signal on the line to be amplified, different parts of the communication network to be insulated etc.
Thus, CUS converter is widely used thanks to its configurability and operational flexibility which enable it to be used in the most different applications.
CUS ensures the galvanically-isolated conversion between the RS-232 side, the RS422-485 side and the supply source.

The main applications are:
- multipoint data transmission networks
- long-distance serial links
- galvanic separation of peripherals
- extension of RS-485 lines.

The main technical characteristics of CUS converters are summarized in the following table:

Supply voltage [V]	230 V a.c. ± 20%
Frequency [Hz]	50-60
Power consumption [VA]	7 max
Power loss [W]	3.5
RS232 Connection	Sub-D 9 female poles (DB9)
Max. RS232 line length [m]	15
Max. RS485-422 line length [m]	1200
Connection of multidrop units	Max 32

NOTE: For more detailed information see the technical catalogue “System pro M compact”

5 ABB circuit-breakers in Ethernet TCP/IP networks

5.1 Ethernet

Nowadays Ethernet is the dominant technology in local networks, for example those used in offices to interconnect personal computers. However, Ethernet applications are extending to other areas, such as telephony and industrial control.
The name Ethernet was used for the first time in 1970 to indicate a communication protocol via radio among different computers.
All the connected devices, shared the same transmission and reception channel. Then a very simple mechanism was devised which allowed each device to transmit - whenever necessary – without the presence of an arbitrator (master or central controller).
Then, the same mechanism was used to implement Ethernet networks, like the present ones, which connect computers via cable. In both cases, the purpose is to allow each node of the network to transmit within an acceptable time, avoiding that two or more devices transmit at the same time (there is a single channel and, if the two transmitters operate simultaneously, the interferences between the forwarded data will make them unusable).

Here is a simple description of how Ethernet works:
- when a computer must transfer a data packet, first it checks if another computer is already transmitting: if this is the case, it waits until the data transfer is over;
- when the channel is free, the computer starts transmitting;
- if two computers begin data transfer simultaneously, both realize it since they detect an interference; then, both stop transmitting and wait a variable time randomly defined between a minimum and a maximum, and then try again to transmit;
- after the transmission of a data packet, the sender must observe a minimum wait before transmitting the next one. This precaution shall prevent that which must transmit a lot of data in sequence from completely occupying the network for a long time. The fact that the data are split into packets ensures access in sequence to the network to all connected devices.

The described procedure offers several advantages:
- Ethernet is a peer-to-peer communication system since all devices are equal as regards communication methods and access to the transmission medium. In particular, the presence of a central controller to assign priority and permission to transmit is not necessary. In addition to being a critical element in case of fault, the controller should be configured with the data of the devices in the network: how many, which ones, transmission priority, etc., an operation which is generally complicated and not within the user's reach;
- all devices can have access to the network whenever necessary (when they have some data to transfer), and leave the network free when they do not use it;
- it is not necessary that priority or other parameters relevant to communication are assigned to the single devices;
- it is possible to add or remove devices at any moment without disturbing the network activity and without carrying out configuration operations (Note: addition or removal of nodes, very common in office environment, is rarer in industrial environment);
- "crossed" communications are possible: the device A can send data to B and the device C can send data to D without neither of the two couples has to take into consideration the other;
- since all devices are connected to the same bus, it is possible to transmit one to one (broadcast) or one to many devices (multicast);
- as the traffic on the network increases, the performances (average transmission times) gradually get worse and worse.

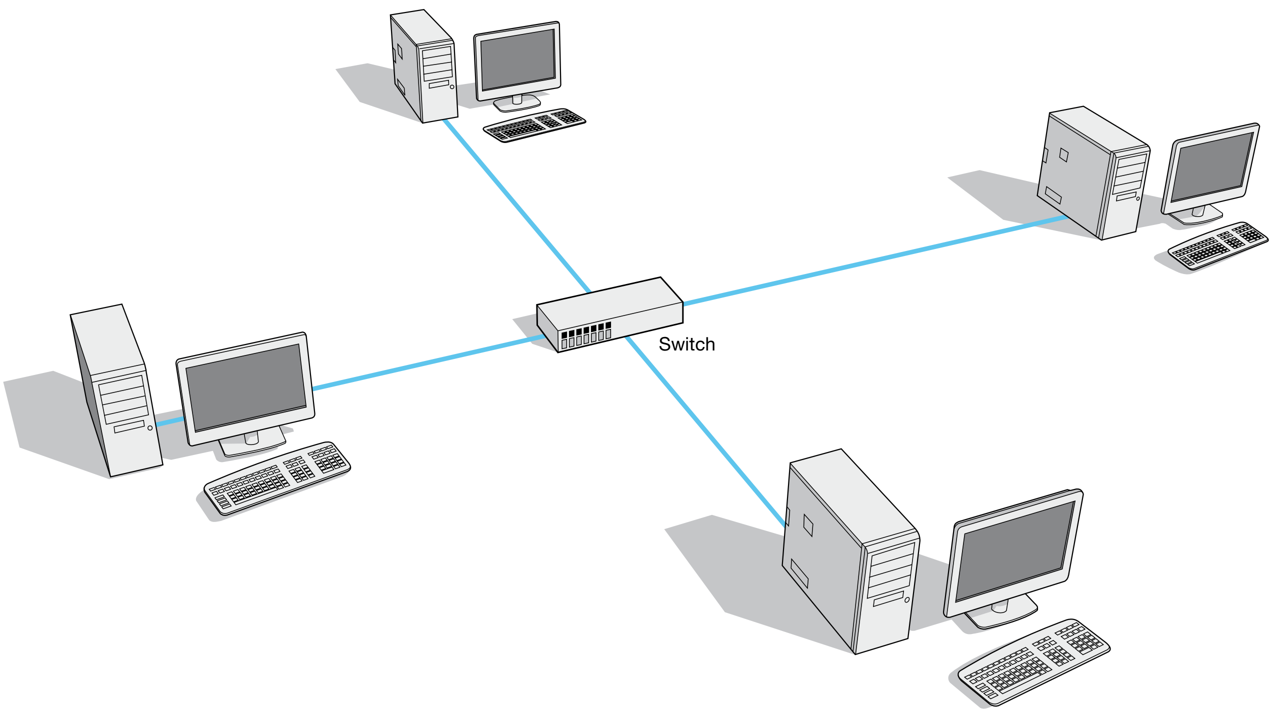
In the course of the years these advantages have determined the development of a well-established technology: cables, hardware interfaces, connectors and mechanical components are largely standardized, which allows a reduction in the total cost of the communication system.
The use of Ethernet in industrial control systems is also based on standardized components (e.g.: shielded twisted pair cable (STP), RJ45 connectors, which are widespread in Ethernet industrial applications even if more suitable for office applications, or M12 connectors), but more resistant to mechanical and thermal stresses, vibrations, high humidity, electromagnetic interferences, dust and chemical agents which might be present in industrial environments. For this reason we generally speak of components for industrial Ethernet.
However, the described mechanism suffers some limitations. The main one is the lack of certainty of transfer times; since a collision is always possible, the time necessary to transmit a single datum cannot be definitely known. The more collisions occur, the more frequently the packets experience delays.
Because of the random waiting time after a collision, it is possible that many subsequent collisions occur (if both the devices randomly select the same delays).

It is theoretically possible, even if little likely, that a packet may have to wait for a long time before being delivered.
Ethernet is said to be the transmission system with non-deterministic delays, since it is impossible to set a maximum time within which a packet shall be transmitted with absolute certainty. What is possible to do is to set the likelihood that the packet is transmitted within a definite time.
Due to this lack of determinism, Ethernet cannot be used in some applications where time control must be extremely strict (for example real-time position control of electric drives).
In all other cases, Ethernet can be used without problems provided that the control or supervision system adopted takes into account the uncertainty of the transfer times.

Even if Ethernet has been originally developed as a bus, with all devices connected in parallel to the same cable, current Ethernet systems are usually wired in a star topology. In the center of this type of networks there is a Switch, which may be either passive (that is a device which simply connects the cables) or active, when it is equipped with an electronic card.

Active Switches can store the addresses of the devices connected to their ports and can store the data packets in order to direct them from the sender to a specific recipient, without involving the other connected devices and with the result of improving the network performances. Switches are used for routing within local area networks (LAN), namely networks which connect computers and terminals physically near one another, for example located in the same building.

Figure 33: Star network with Switch Ethernet



5.1.1 IP protocol

The IP control (Internet Protocol) allows a device on a local network to communicate with another device located on another local network, provided that the source network and the destination one are somehow interconnected. This interconnection can be realized with any number of intermediate networks. The protocol is based on the presence of routing devices (router[8]) which make the packet be delivered from one network to the other up to destination.
The power and the utility of the IP protocol is that it is not necessary for the sender to know the pathway that the data packet shall follow to reach its destination. The IP system works like a mail system, caring that a data packet, marked with the recipient address, travels up to its destination.
As a matter of fact, the different packets transmitted by a sender could reach the same recipient through different pathways since the routers could decide different routes from time to time, according to the network situation, traffic, etc.

The IP control describes in details:
- what a device must do to send a data packet to another device or to send a response to a received packet;
- the behavior of the devices which make the packets travelling from a network to another one to reach their destination.

The details of the protocol are not of our interest and are not dealt with in this document. It is enough to know that the address of the recipient and the address of the sender, as well as those of each device connected to the network, consist of 4 numbers (byte) in sequence, for example 10.39.1.156. These numbers form the IP address; in the future versions of this protocol the IP address shall be extended to 6 numbers.
On a system of interconnected networks, both an Internet network as well as an Intranet company network having the same IP-based architecture, there cannot be two devices having the same IP address at the same moment. This is to guarantee that an address corresponds to a single device.

Before a device being able to exchange data on a network, it is necessary that it is assigned a distinct IP address. This operation can be done by the user/operator/panel builder, who assigns the desired address and verifies that there are no overlaps (then we speak of static IP address). Otherwise it is possible to have on the network a server which automatically assigns a free IP address to each device which is connecting to the network, in which case we speak of dynamic IP address. The mechanism of such automatic assignment is described in the DHCP protocol (Dynamic Host Configuration Protocol of addresses), which we do not need to analyze thoroughly now and which is not the subject of this document.
The main difference between the two types of address is that, in case of static IP, the address is usually stored in a permanent memory and therefore it does not change if the device is switched off and then switched on, or disconnected from and then reconnected to the network. But, in case of dynamic assignment, a new device, or a device which reconnects after a disconnection, may be assigned any of the free available IP addresses. As a consequence, after any shutdown or disconnection, the IP address of a device may change.
Industrial control systems usually require that each device has a defined address; consequently, static assignment of the IP address is largely the most used system.

5.1.2 TCP protocol

The TCP protocol (Transmission Control Protocol) has the task to control data transmission; each communication (e.g.: sets of data, files or Web pages), exchanged between two devices is divided into parts of similar length, named packets, and each packet is separately sent over the network to the destination device. Thanks to the TCP protocol, the recipient is able to restore (in the correct order) the single packets received, thus reconstructing the sent communication.
In practice, through the IP protocol, a device is able to make a data packet reach any device, whereas the TCP protocol uses the IP protocol to allow transfer of structured data systems from a device to another in a reliable and correct way.

For example, when it is necessary to transfer a file or a Web page from a PC to another one, various operations must be carried out; here is a simplified description of the process:
- a logical connection must be established by sending a series of packets to indicate the intention of transmitting a file and even indicating the type and dimension of the file; a response confirming that the other computer is ready to accept the transmission is sent back;

[8] A router is a device which determines the optimum route (communication path) of some information through a network (routing), that is the suitable path to route the data packets from a network to another one. As a matter of fact routers applying IP protocol do not have at their disposal all the information about the route of the data packets, but only a local piece of information: on which path to route a packet intended for a defined address.

- the transmitting computer, through the TCP protocol, shall split the file into data packets, number them and, through the IP protocol, send them one after the other. Since the transmission is carried out through the IP protocol, the packets might arrive with different delays, or in a different order with respect to the original one;
- the receiving computer, through the TCP protocol, shall reorder the packets according to their numeration and check that all the packets have arrived; in case some packet has got lost, the recipient shall ask the sender to transmit it again;
- once the correct and complete reception has been verified, the two computers exchange some packets indicating that the operation has been completed and the logical connection closed.

As it can be seen, whereas the IP protocol relates to routing and delivery of a single data packet, the TCP protocol is intended for the use of data packets to transmit the quantities of data required and restore the received data. These two protocols are commonly used together, and as a matter of fact TCP/IP is often referred to as a single protocol.

The possibility of using TCP/IP-based protocols is one of the factors which contributed to the spreading of industrial Ethernet technology, for example for the automation of production systems or for the control of electrical systems for the generation, distribution and management of electrical energy.

5.2 Ethernet industrial protocols

When wishing to use Ethernet as communication medium for industrial control, it is necessary to specify in details what protocols are employed. In fact, Ethernet can be used for many different applications, each of them having a well-defined set of protocols. Indicating that TCP/IP is used, which actually occurs in the most cases, does not complete the picture. In fact, as previously mentioned, TCP/IP defines a set of protocols which perform data transport from one device to another, passing through one or more interconnected networks. But TCP/IP does not give information about the transported data, or the application using them. For example, just consider that TCP/IP is equally used to transfer files (ftp protocol), Web pages (http protocol), electronic mail (SMTP protocol), and videos to be shown in real time (streaming); each of these applications has different protocols.

In an industrial control and supervision system, once Ethernet has been chosen as communication medium and TCP/IP as transport protocol, the following is still to be defined:

- data format: e.g., how many bytes are transmitted at a time? how are numbers represented?
- meaning of data: e.g., how can a measure, an alarm indication or a control signal be distinguished?
- behavior of the devices transmitting and receiving data: e.g.: how often does the transmission of a measure occur? what happens if a datum gets lost or arrives late?

As it is evident, the details to be described are numerous, such as the problems which may occur. Designing this type of protocol requires an effort out of the reach of most manufacturers of devices and systems.

Besides, if each manufacturer of devices and systems chose his own solution, there would be total incompatibility, thus undoing the main advantage of Ethernet and TCP/IP: that of being the standard technologies which can be used also to connect devices of different manufacturers.

For these reasons, in recent years, industry has defined various “standard” protocols for the use of Ethernet in industrial environments. At least a dozen protocols are currently widely spread and about as many are used for particular applications.

Any developer of control and automation systems chooses among the available protocol that which better satisfies his application requirements.

5.3 Modbus/TCP protocol

Developed in 1999, Modbus/TCP was one of the first industrial protocols to use Ethernet and TCP/IP. As the name itself indicates, this is an adaptation of the traditional Modbus protocol (on a serial port) to the networks using TCP/IP. Its main advantages are:
- simplicity, which makes it easily implementable both in new devices as well as in adaptations to existing devices;
- similarity to the traditional Modbus protocol, already known by many programmers and developers of control and supervision systems;
- existence of devices to interconnect, through Ethernet networks, devices using the traditional Modbus on a serial port; as you can see below, these devices work by converting the single telegrams.

The concept is quite easy: the master-slave architecture is replaced (see clause 4.7.1) with a client-server architecture. The sensor or actuator works as server, a device providing for other devices (the clients) which require it, data to be read or memory spaces in which to write. This representative model is the same as in the traditional Modbus protocol, whose data are registers which can be either read or written.
The client is the device wishing to read or write the data; to do it, it sends a request telegram to which the server replies with a response telegram.
The structure of the telegram is the same as in the traditional Modbus, both as regards length and codification:
- the request of reading consists of a command (indicated in the "Function Code") specifying the type of action to be performed (e.g.: reading of the data) followed by the address of the register or registers to be read (the information are included in the field "Data" of the telegram);
- the request of writing comprises: command (indicated in the "Function Code"), address and data to be written (included in the field "Data");
- the response telegrams, to indicate that the command has been successfully completed, repeat the command (if necessary followed by the required data); instead, if the command cannot be carried out, they include an error code (exception response).

The data format is the same as in traditional Modbus, and also the codes (Function Code) used to indicate the reading and/or writing functions and the errors (exception response code) are the same. This allows system developers to reuse a large part of the code already written in order to implement traditional Modbus. Besides, this allows single telegrams to be converted, with no need to store additional data and without loss of information.

Figure 34: Traditional Modbus telegram (Modbus RTU).

Slave Address	Function Code	Data	CRC

- **Slave Address:** this field contains the address (Modbus) of the slave device connected to the traditional Modbus serial line;
- **Function Code**: this field contains the code used to indicate the actions to be carried out (e.g.: functions of reading and/or writing in the registers of the slaves);
- **Data**: this field may contain additional information useful to carry out the actions defined in the "Function Code"; for example, when a master sends a request of data reading to a slave, the field "Data" of the telegram shall contain the address of the register from which data reading must be started and the number of registers (data) to be read. If no errors occur, the response telegram from the slave shall include in the field "Data" the data requested by the master;
- **CRC**: field used to monitor and manage the communication errors.

NOTE: For further information see the document: "MODBUS Protocol Specification", available on http://www.modbus.org/specs.php.

From the traditional Modbus telegram (e.g.: Modbus RTU), it is possible to get to a Modbus/TCP telegram by:

1) removing the fields "Slave Address" and "CRC" from the traditional Modbus telegram;

2) adding the MBAP Header (Modbus Application Header) to the start of the message.

As explained hereafter, the field "Slave Address" is inserted in the field "UnitID" of the Modbus/TCP telegram when the server is a gateway for the conversion from Modbus/TCP to ModbusRTU protocol.

The MBAP Header contains the following fields:
- Transaction identifier: 2 bytes, set by the Client in the request and duplicated by the Server in the response, used to univocally identify a transaction (a specific request sent by the Client to the Server);
- Protocol identifier: 2 bytes, to identify the protocol (the Modbus protocol is identified by the value 0);
- Length: this field (2 bytes) identifies (counts) the length (in bytes) of the subsequent fields present in the message;
- Unit Identifier (hereafter called "Additional Address"): this field (1 byte length) allows the Modbus map to be extended, thus permitting a single server to answer as if consisting of different devices (virtual units). When the server is a gateway which connects a Modbus serial line to an Ethernet TCP-IP network, this field is used to identify any connected remote slave (see Figure 36).

For further information see the document "MODBUS Messaging on TCP/IP Implementation Guide V1.0b", available on http://www.modbus.org/specs.php.

Figure 35: Modbus /TCP telegram

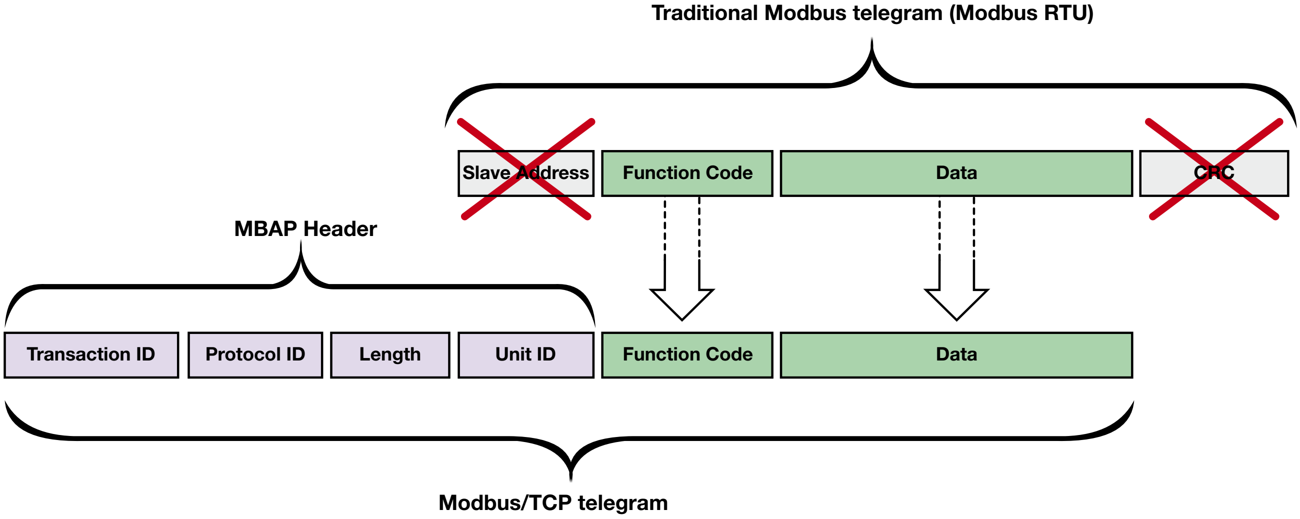
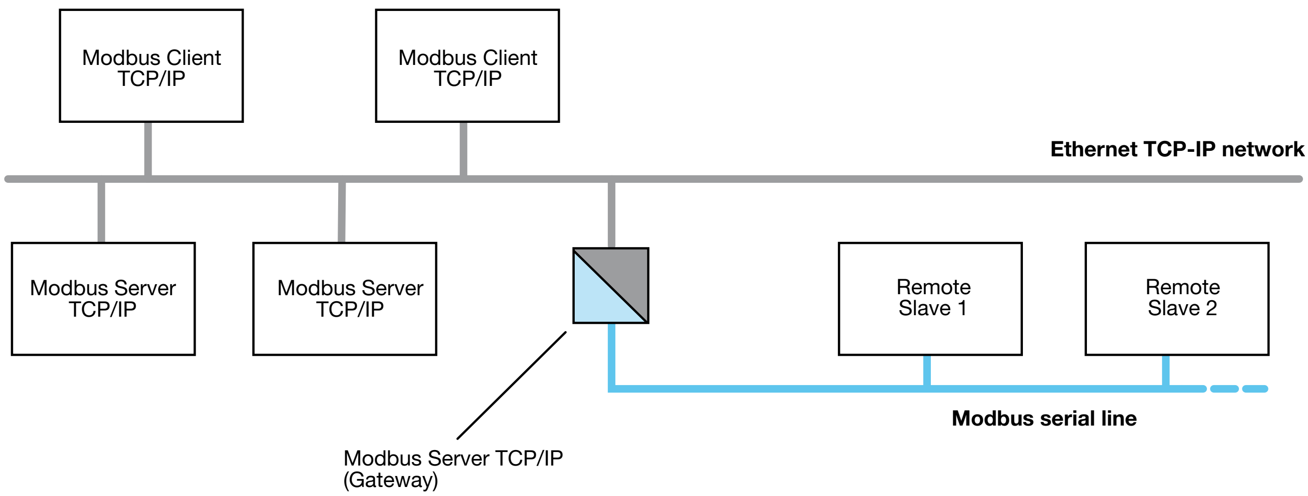


Figure 36: Ethernet TCP/IP network - Modbus serial line



The Modbus/TCP telegrams contain a field named “Additional Address”, which allows a single device (for example a gateway) to have a register map divided into sections (the section 1, 2, 3... of the register map corresponds to the additional address 1, 2, 3); this is used for the conversion between traditional Modbus and Modbus/TCP, as explained hereafter.

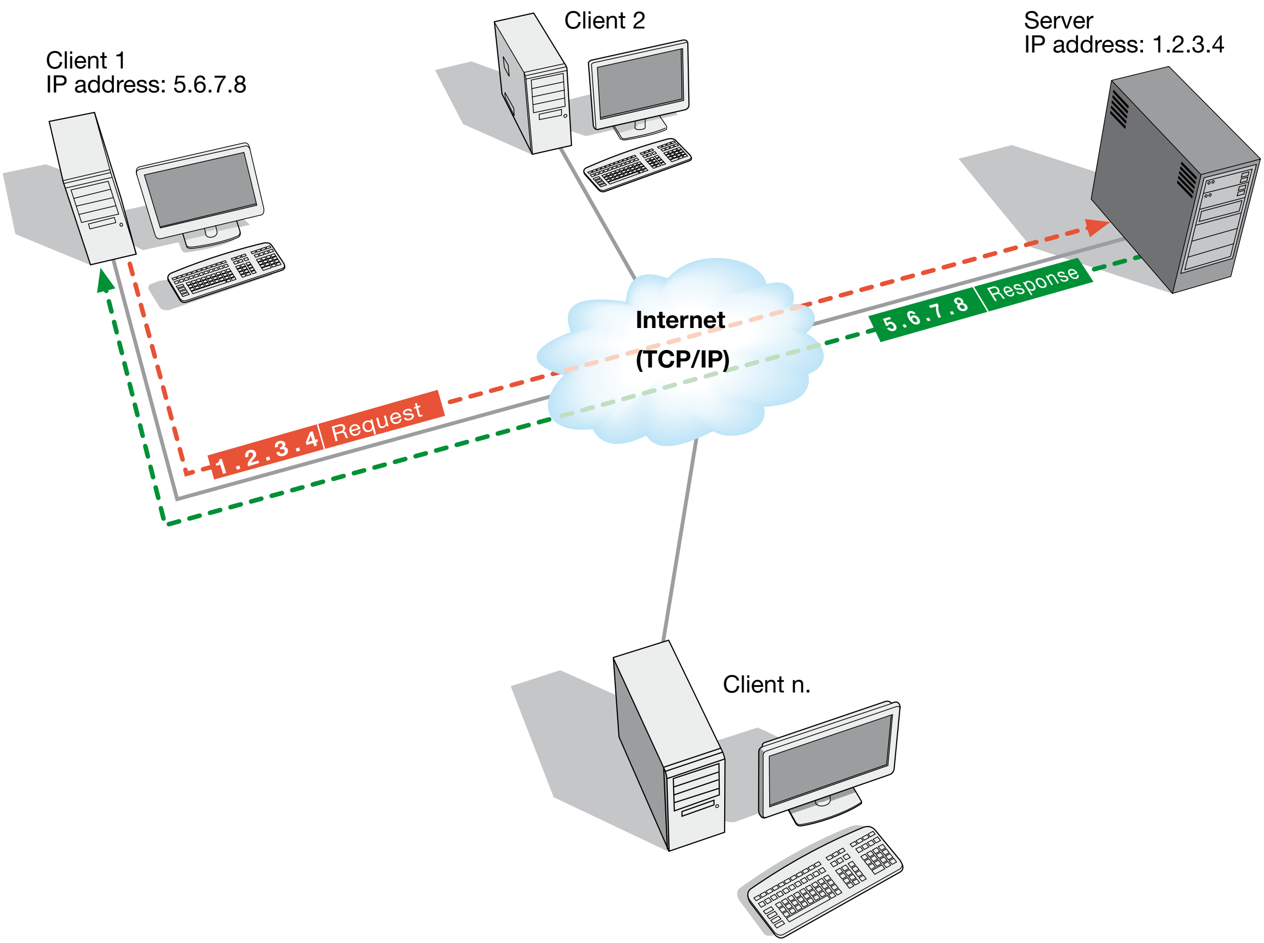
Both the client and the server have an IP address. The server accepts Modbus/TCP telegrams (indicated with registered port 502[9]), from any client; for each telegram a response telegram is built, which is sent to the IP address of the sender (that is the client).
The TCP/IP protocol ensures that:

- the request telegram is transferred from the client to the server and vice versa;
- each response telegram is transmitted to the unit/device which has sent the request and is delivered to destination.

Modbus/TCP communication occurs always through single telegrams; to each request only one single response telegram corresponds, which satisfies the server processing.
This mechanism allows a device to serve simultaneously more applications, by responding alternatively to different clients. For example, a control application can read the data once per second, whereas a supervision application installed on another computer reads other data, always from the same server, once per minute.
Any collision in the transmission of telegrams is processed by the mechanism already present in Ethernet transparently for the applications.
When the server receives request telegrams faster than it can reply, it stores them in queue and answers in sequence; each response shall be correctly addressed to the client which has sent the request.

[9] *The port TCP 502 is specifically intended for Modbus applications; the clients and the servers communicating via Modbus TCP/IP protocol, send and receive data on port 502*

Figure 37: Request/response sequence

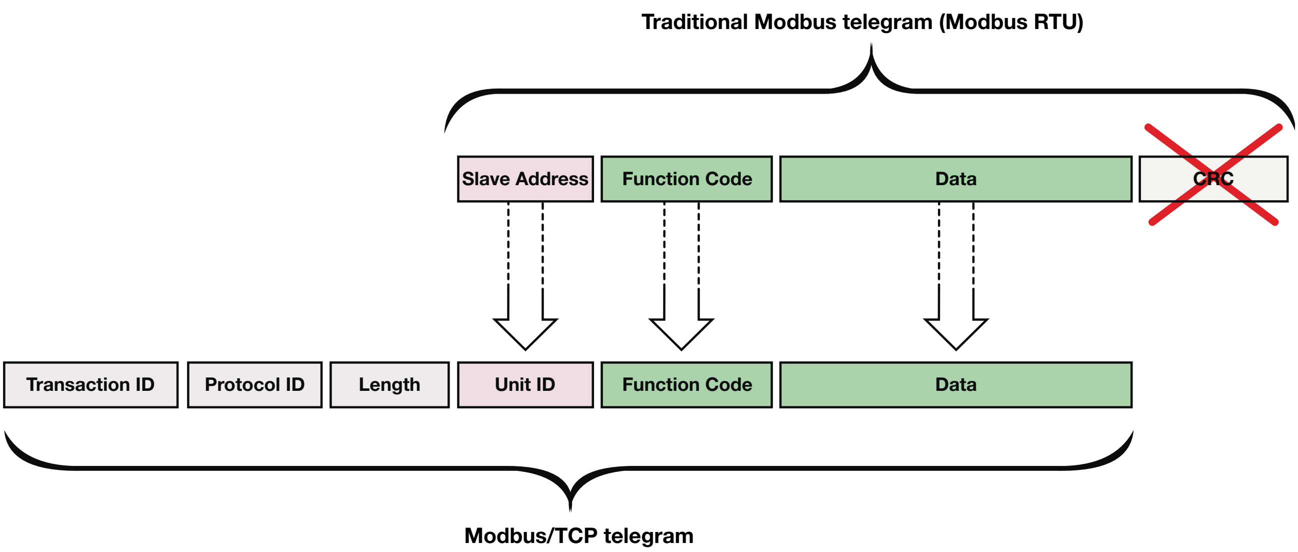


5.4 Serial Modbus -Modbus/TCP conversion

There is often the requirement to upgrade or modify an industrial control and supervision system by adding new devices or by replacing the existing ones. In these cases, the protocols and systems which allow these operations to be performed with the least modifications to the existing devices and software are preferred.
The structure of the Modbus/TCP telegram is particularly suitable for this purpose because:
- to all intents and purposes, the content of the Modbus/TCP telegram, when excluding what is necessary to the delivery on TCP/IP, is a traditional Modbus telegram;
- the telegrams are always treated separately: every request telegram corresponds to one response telegram only.

Therefore, it is possible to interface the existing traditional devices with Modbus/TCP systems by using SD-GEM converter. Such device allows a traditional Modbus serial line to be connected to an Ethernet system since it works as a server on the TCP/IP side, and as a master on the serial side.
From the point of view of the Modbus/TCP, the converter is seen as a single device, with its own register map divided into sections, each of them identified by an "Additional Address" (or Unit ID).
Each section represents the traditional device (the slave Modbus RTU), which has the slave address corresponding to the additional address.
According to this representative model, the conversion is operated through a quite simple mechanism: when the converter receives a request telegram, it takes the content without the TCP/IP part and sends it as telegram on the serial port.
To all intents and purposes this telegram is a Modbus telegram destined to one of the slave devices, which therefore shall reply with another Modbus telegram. The converter shall receive this response, shall insert it as content into a TCP/IP telegram and transmit it to the client (see Figure 38).

Figure 38: Slave Address and Unit ID



Thus, a Modbus/TCP system can have access to all data present on the register map of any Modbus traditional device (e.g.: an automatic circuit-breaker connected on a Modbus serial line).
The following Figures conceptually show an example of reading of the current values (in the three phases and in the neutral) of a SACE Tmax XT4 160, equipped with an electronic trip unit type Ekip LSIG, in an Ethernet TCP/IP network. SD-GEM gateway operates simultaneously both as TCP/IP server as well as Modbus RTU master.

Figure 39: Reading of the currents on an Ethernet TCP/IP network – Request

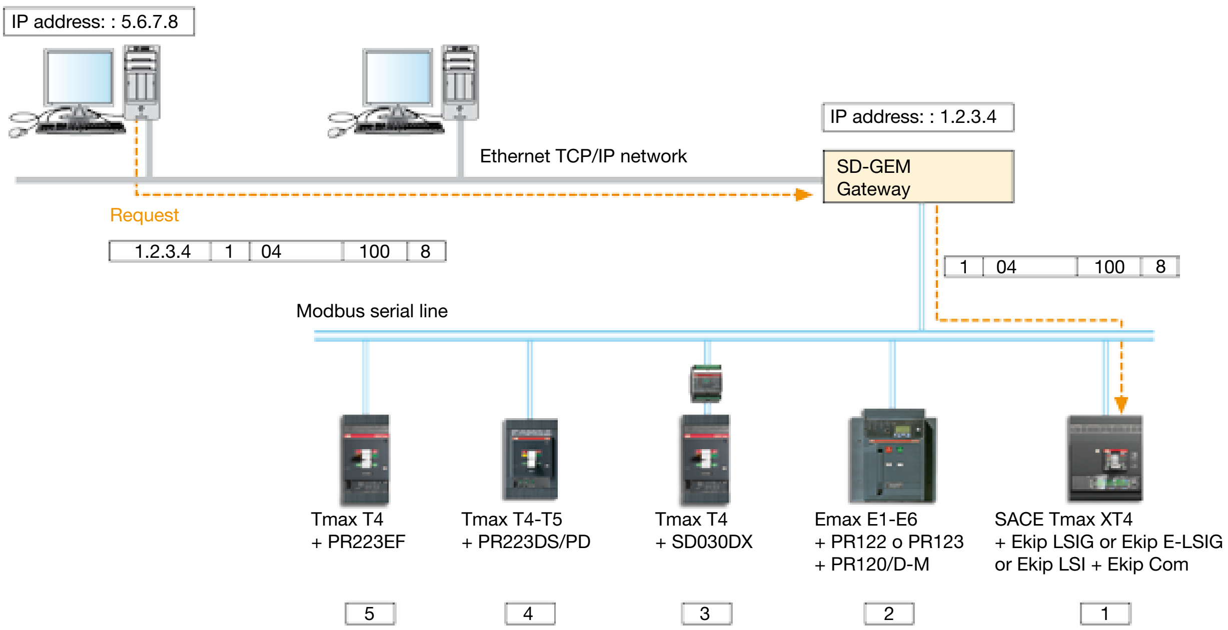
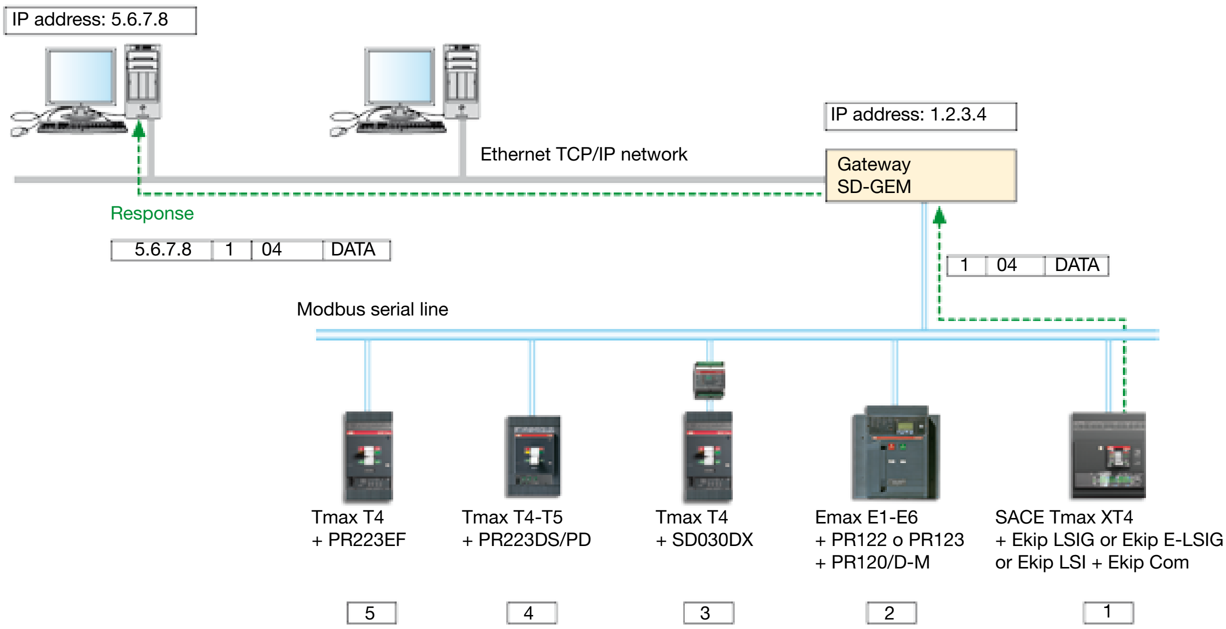


Figure 40: Reading of the currents on Ethernet TCP/IP network – Response



- 5.6.7.8: IP address of the client which has sent the request and which receives the response;
- 1.2.3.4 IP address of the server (SD-GEM) receiving the request;
- 1 (Unit Identifier or Additional Address) of the circuit-breaker Tmax XT4 connected to a Modbus serial line;
- 04 (Function Code): instructions for reading of currents (run time values);
- 100: number of register from which reading of currents starts;
- 8: number of registers to be read (from register 100 to register 107) to get the current values of the three phases and of the neutral.
- DATA: this field contains the values of the currents in the phases (IL1, IL2, IL3) and in the neutral (INe) read by the circuit-breaker.

5.5 SD-GEM gateway

SD-GEM is a gateway[10] which operates the conversion from Modbus/TCP protocol to Modbus RTU protocol, thus allowing ABB low voltage automatic circuit-breakers (with Modbus RTU communication interface) to be integrated into the supervision systems on Ethernet TCP/IP networks (with Modbus TCP protocol).

SD-GEM gateway is equipped with:

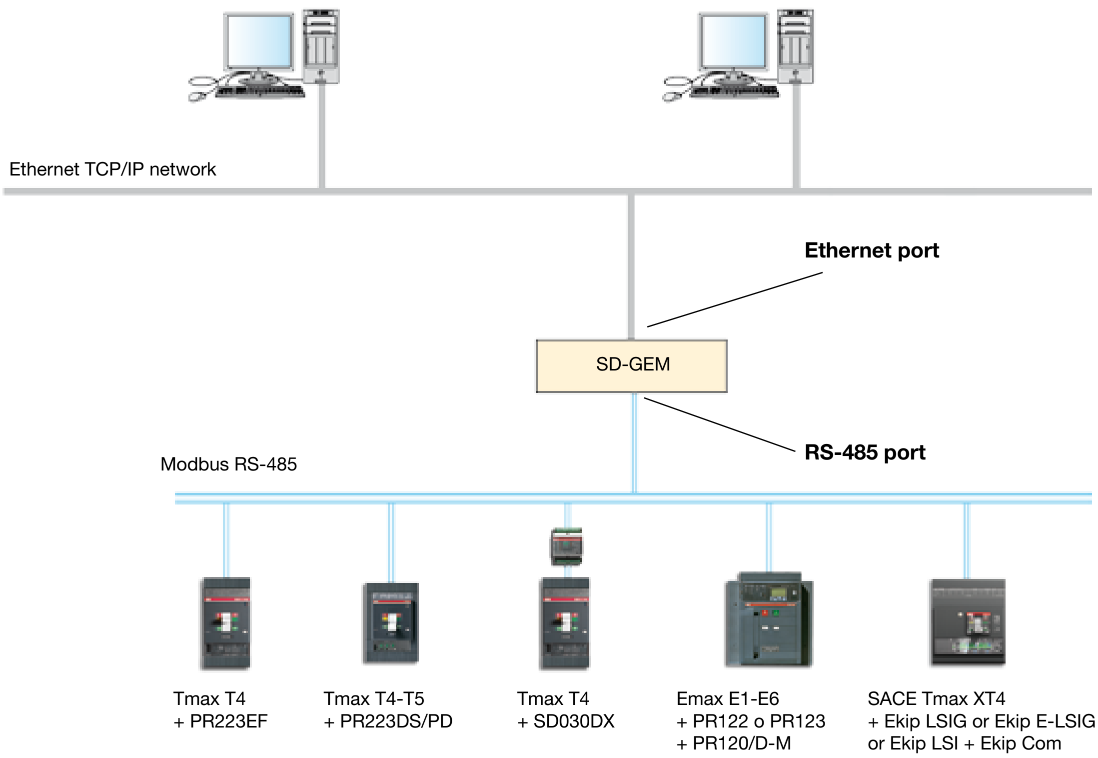
1) a standard serial port RS-485 for the connection to a Modbus serial line.
The field devices (e.g.: ABB circuit-breakers with communication interface), which communicate through Modbus RTU protocol, are connected to this serial port. Such devices, connected in a bus network, must be communication slaves, that is to say they are only allowed to reply to the queries of the master and they cannot transmit on their own initiative. From the side RS-485, SD-GEM operates as a Modbus RTU master (see clause 4.7.1 “Modbus RTU system functioning”). Maximum 31 devices can be connected to the serial port RS-485.

2) an Ethernet port for the connection to Ethernet TCP/IP networks via Modbus TCP protocol.
Thus, SD-GEM allows a client, which communicates via a Modbus/TCP protocol (e.g.: a PC or a SCADA) connected to an Ethernet TCP/IP network, to exchange data with the devices connected to a Modbus serial line.

From a client (e.g.: a PC) connected on an Ethernet TCP-IP network it is possible to communicate with a remote slave on a Modbus serial line by specifying the IP address assigned to SD-GEM and the address (Unit Identifier or Additional Address) of the remote slave to be queried.
As described in clause 5.4, SD-GEM converts the Modbus/TCP messages coming from a client, into Modbus RTU messages, and deliver them, through its serial port RS-485, to the devices connected to the Modbus network (in particular to the device which has received the query by the PC).
The queried device sends a response to SD-GEM through a Modbus RTU message; once the response has been received, SD-GEM converts it from Modbus RTU to Modbus/TCP and sends it via Ethernet to the client which has sent the query.

[10] Gateways are appliances used to connect different devices over a network. They have their own microprocessor and process memory to manage the conversions of different communication protocols. A gateway is an interface able to couple data transmission systems of different type (e.g.: an Ethernet TCP/IP Network with a Modbus RS485 serial Line). A gateway usually needs hardware support for the connection to both systems and a software for the conversion of the messages.

Figure 41: SD-GEM in Ethernet TCP/IP network



The devices equipped with interface Modbus RTU on RS-485 can be connected to SD-GEM gateway. In particular, regarding ABB automatic circuit-breakers, the following devices can be connected:

Device	Trip unit
Circuit-breakers SACE Tmax XT2-XT4	Ekip E-LSIG + Ekip Com communication module Ekip LSIG + Ekip Com communication module Ekip LSI + Ekip Com communication module Ekip M-LRIU + Ekip Com communication module
Circuit-breakers Tmax T4, T5 and T6	PR222DS-PD PR223DS PR223EF
Circuit-breakers Tmax T7 - Emax X1	PR332/P + communication module PR330/D-M PR333/P + communication module PR330/D-M
Circuit-breakers Emax E1÷E6	PR122/P + communication module PR120/D-M PR123/P + communication module PR120/D-M
Circuit-breakers Emax DC	PR122/DC + communication module PR120/D-M PR123/DC + communication module PR120/D-M
Circuit-breakers Emax E2/VF-E3/VF	PR122/VF + communication module PR120/D-M
Flex interface SD030DX	Thermomagnetic or basic electronic trip unit (for details see clause 4.5)

Since SD-GEM carries out a generic protocol conversion, in addition to automatic circuit-breakers, it is possible to connect to RS-485 port also any other device which implements Modbus RTU protocol, provided that it operates with the same parameters of the serial port (baud rate, number of bits, parity bit, stop bit - see clause 4.7.1 and Annex G).

For the communication on Ethernet TCP/IP networks, please remember that it is necessary to supply the trip units with 24 V DC auxiliary voltage (for the relevant characteristics see Annex B).

The data, alarms and measures made available by each trip unit are summarized in Table A.1 (for Emax E1÷E6, Emax X1 and Tmax T7 circuit-breakers), in Table A.2 (for Tmax T4, T5 and T6 circuit-breakers) and in Table A.3 (for SACE Tmax XT2 and XT4 circuit-breakers) of Annex A.
During the operation, SD-GEM must be supplied with 24 V DC auxiliary voltage.
For more detailed information please refer to the relevant catalogues and product technical manuals.

6 Application examples

Here are some examples of application of ABB SACE circuit-breakers, with dialogue option, for:

- supervision of protections and switching of circuit-breakers;
- energy costs allocation inside a plant;
- management of priority and non-priority loads of an installation.

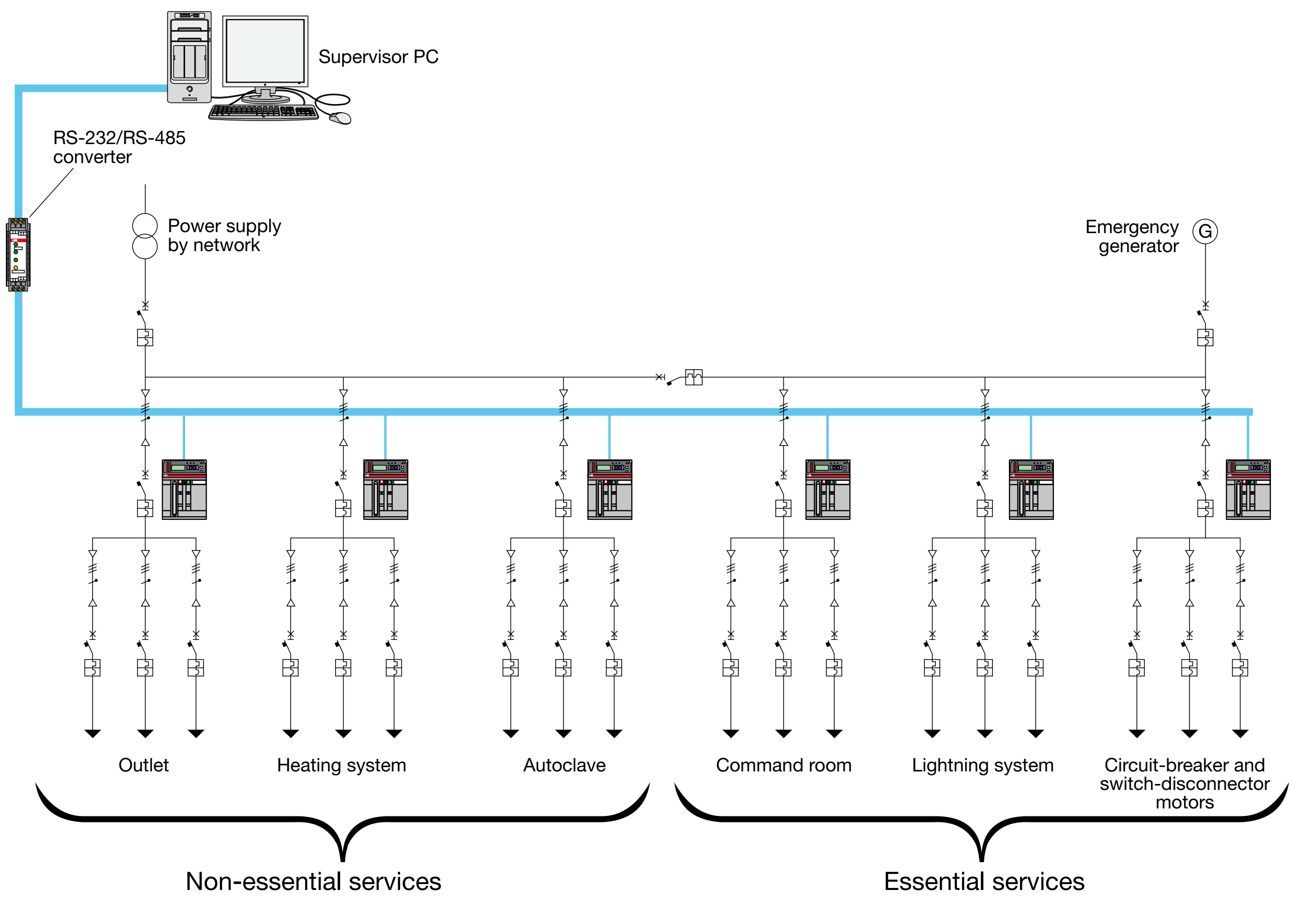
6.1 Supervision of protections and circuit-breaker switching

Take into consideration a power plant. In these types of installation it is very important to keep under control, besides the power production process, also all the circuits which supply the auxiliary services (command room, heating system, circuit-breaker and switch-disconnector motors, fire prevention system, ambient lightning, outlets, etc.). These are low voltage circuits.

Then there is also a system with an emergency generator, which supplies the essential services only.
Each switchboard has got, as main circuit-breaker, an Emax equipped with PR122/P-PR123/P trip unit. PR123/P is used only for the switchboards relevant to the essential services which can be supplied by the emergency generator, because it has the possibility of using the dual setting function: it can store the settings of the protections, both for the normal condition with power supply from the network, as well as for the emergency condition, with power supply from the auxiliary generator unit, and to switch instantaneously from one to the other in case of need.
PR122/P and PR123/P trip units are all provided with Modbus communication interface (PR120/D-M auxiliary module) and connected to the supervision system.

The supervision system, interfacing with the circuit-breakers over a bus communication network via Modbus protocol, displays three types of information relevant to

Figure 42: Diagram of the auxiliary service of a power plant



the auxiliary systems:

- alarms for protection overloads;
- data relevant to the protection trips (in case of trip, both the values of the interrupted currents as well as the waveforms recorded by the trip unit in the internal data logger, are displayed);
- data relevant to the life of each circuit-breaker (number of operations and percentage of contact wear).

The supervision system reads cyclically the information contained in each circuit-breaker via the communication bus.
The alarm and trip data of the protections are made available for the operators in the control room and stored in the history database of the supervision system.

Thanks to the available data it is possible to:

1) monitor in real time the state of the circuits supplying the auxiliary services;

2) carry out a diagnostic and statistic analysis of the occurred anomalies for a preventive study on the fault causes in order to reduce the inefficiencies of the auxiliary systems, thus making more efficient the logistic management of the plant.

In addition, also the data relevant to the life of each circuit-breaker (e.g. number of operations carried out and percentage of contact wear) are transferred over the local network to the database and used to schedule the preventive maintenance on the circuit-breakers in order to guarantee operation continuity of the essential services.

6.2 Allocation of the energy costs inside a plant

In a manufacturing process it is very important to know the energy cost associated to the different manufacturing lines in order to allocate correctly the various manufacturing costs for each type of product.

Take into consideration an industrial plant for the production of cleansing agents with three different manufacturing lines. Each line produces one type of detergent, distinct due to composition, packaging and final packing. These lines carry out similar manufacturing processes starting from various mixtures of raw materials. The three lines need to produce different quantities of product and therefore also the running times are planned independently: at a definite instant, one of the lines can work at full speed, while the others may not be running.

For a correct management of the plant, it is necessary to know the energy costs referred to each type of production.
In particular, the energy supply costs to be taken into account are:

- the direct cost of energy, proportional to the number of kWh consumed by each manufacturing line;
- the penalties relevant to the reactive power, proportional to the number of minutes during which the cosφ of the plant has been lower than the value fixed by the power supply authority of the electrical network.

6.2.1 Description of the distribution and communication system

The electrical plant has a LV radial distribution structure. Each line is supplied by means of a process switchboard (QBT-PR), which delivers power to the real production plant, and a switchboard for the automation of the packing system (QBT-AU), which supplies the machines for the bottling and handling of the packages.
Each of the switchboards uses as main circuit-breaker an Emax E2 equipped with the following accessories:

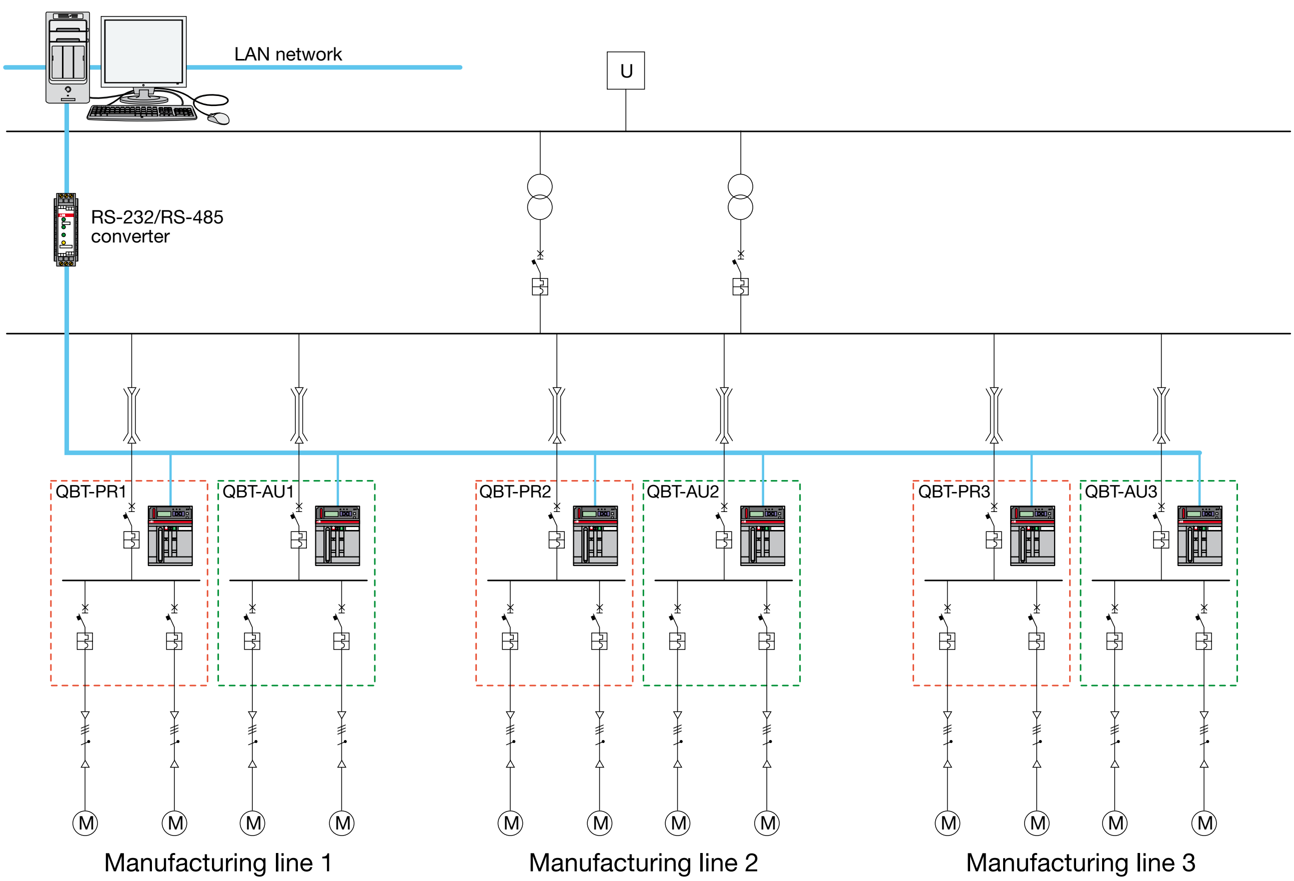
- PR122/P trip unit;
- PR120/V voltage measuring module;
- PR120/D-M Modbus communication module.

The trip units are supplied at 24 Vd.c. by ABB switching power supplies type CP-24/1 each one of them positioned in a main switchboard.
All the main circuit-breakers are connected, through a communication bus RS-485, to a personal computer on which the supervision application is installed. The computer is, in its time, connected via a local network with the control systems of the plant.

6.2.2 Functioning

The presence of PR120/V modules allows the trip unit of each main circuit-breaker to measure continuously active power, reactive power and cosφ relevant to its own load. The trip unit is provided with an energy meter in which the total active power value is stored moment by moment.
All the above mentioned products are available as input registers accessible for reading via Modbus protocol.

The supervision application carries out a very simple cycle which consists in querying each of the circuit-breaker, in reading the registers of total accumulated energy and in measuring the reactive power. For instance reading can be made once in 5 secs.
Once in 15 minutes, the application program writes in a file the values of total energy and of average reactive power for each circuit-breaker. Then, such values are read by the people responsible for cost allocation, thus allowing to know the use of active and reactive power consumed by the plant and to share the costs among the different production lines.



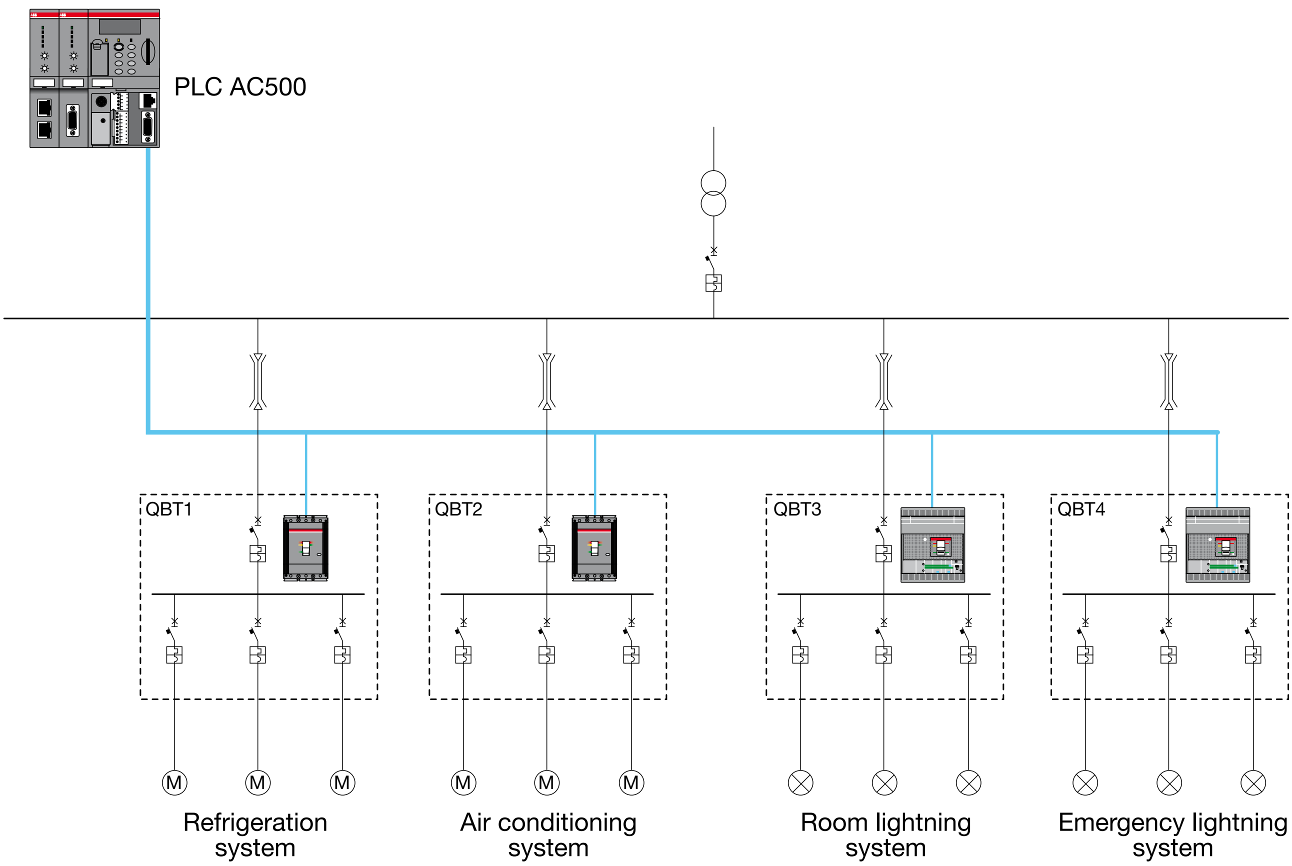
6.3 Management of priority and non-priority loads

In a shopping mall there are various refrigerating rooms, each of them equipped with independent refrigeration system. The refrigeration system of each room is provided with its own thermostat and starts automatically and independently.
Moreover, each refrigeration system is able to run in normal mode (in steady state) or in fast mode when the room is filled with new products which need to be cooled as quickly as possible. In this last case, a power peak occurs.
The distribution system supplies, in addition to the refrigerating rooms, also room lightning, air conditioning and external emergency lightning. The last is considered a non-priority load and, when necessary, can be disconnected to reduce energy consumption.

The main circuit-breakers QBT1 and QBT2 of the sub-distribution switchboards are Tmax T5 with PR222DS/PD electronic trip unit (equipped with Modbus communication interface) mounting the auxiliary contacts with electronic interface AUX-E and motor operator with electronic interface MOE-E. The main circuit-breakers QBT3 and QBT4 of the sub-distribution switchboards are SACE Tmax XT4 with Ekip LSI electronic trip unit, Ekip Com communication module (Modbus communication interface) and motor operator with electronic interface MOE-E.
The circuit-breakers are all connected to the same Modbus communication bus type RTU, whose master is a PLC AC500 with RS-485 interface.

The PLC implements an application software for the control of loads: it reads cyclically the current values from the main circuit-breakers and commands opening of those of the non-priority loads, whenever the sum of the currents exceed a set threshold, or under other programmed working conditions.
These conditions vary according to the time schedule, since the kWh peak can be differentiated for time bands (more expensive by day and in the consumption peak hours, less expensive by night).

The load control acts mainly pursuing two aims:
- to prevent the main protection of each sub-distribution switchboard from overload tripping;
- in addition, if possible, to keep the load curve as low as possible in the hours when the kWh cost is higher.



Annex A: Measures, data and commands for supervision and remote control

Supervision with fieldbus Modbus RTU

Table A.1: Measures-data-alarms and commands available with Emax air circuit-breakers, X1 air circuit-breakers and Tmax T7 moulded-case circuit-breakers

		E1÷E6			T7-X1		X1
		PR122/P+ PR120/D-M	PR122/P+ PR120/D-M+ PR120/V	PR123/P+ PR120/D-M	PR332/P+ PR330/D-M	PR332/P+ PR330/D-M+ PR330/V	PR333/P+ PR330/D-M
Electric quantities	Phase currents (IL1, IL2, IL3), neutral current (IN), ground current	■	■	■	■	■	■
	Voltages (phase-to-phase, phase-to-neutral, residual)		■	■		■	■
	Total and phase power (active P, reactive Q, apparent A)		■	■		■	■
	Power factor		■	■		■	■
	Peak factor (Ip/Irms)	■	■	■	■	■	■
	Frequency		■	■		■	■
	Total and phase energy (active, reactive and apparent)		■	■		■	■
	Harmonic analysis (THDi, THDv and spectrum) up to 40th harmonic (up to 35th with f= 60 Hz)			■			■
	Waveform of phase and neutral currents			■			■
	Waveform of the line-to-line voltages			■			■
	Data logger	■	■	■	■	■	■
	Measures history (Imax)	■	■	■	■	■	■
	Measures history (Vmax, Vmin, Pmax, Pmean, Qmax, Qmean, Amax, Amean)		■	■		■	■
State information	Circuit-breaker state (open/closed/tripped)	■	■	■	■	■	■
	Circuit-breaker position (racked-in/test isolated)	■	■	■	■	■	■
	Spring state (charged/discharged)	■	■	■	■	■	■
	Mode (local, remote)	■	■	■	■	■	■
	Protection parameters set, parameters for the load control	■	■	■	■	■	■
Maintenance data	Total number of operations and trips	■	■	■	■	■	■
	Number of test trips and manual operations	■	■	■	■	■	■
	Number of trips separated according to each protection function	■	■	■	■	■	■
	Contact wear (%)	■	■	■	■	■	■
	Data records of the last 20 trips	■	■	■	■	■	■
Protections alarms	Protection L, S, I, G	■	■	■	■	■	■
	Directional protection D (timing and trip)			■			■
	Protection against unbalanced phase currents U (timing and trip)	■	■	■	■	■	■
	Protection against overtemperature of the trip unit OT	■	■	■	■	■	■
	Protection against unbalanced phase voltages U (timing and trip)		■	■		■	■
	Protection against undervoltage UV (timing and trip)		■	■		■	■
	Protection against overvoltage OV (timing and trip)		■	■		■	■
	Protection against residual voltage RV (timing and trip)		■	■		■	■
	Protection against reversal of active power RP (timing and trip)		■	■		■	■
	Protection against under-frequency UF (timing and trip)		■	■		■	■
	Protection against over-frequency OF (timing and trip)		■	■		■	■
Diagnostic alarms	Trip command failed	■	■	■	■	■	■
	Contact wear = 100%	■	■	■	■	■	■
	Rating Plug error	■	■	■	■	■	■
	Trip coil (TC) disconnected or damaged	■	■	■	■	■	■
	Current sensors disconnected	■	■	■	■	■	■
Commands	Circuit-breaker opening/closing	■	■	■	■	■	■
	Alarm reset (trip reset)	■	■	■	■	■	■
	Setting of protection curves and thresholds	■	■	■	■	■	■
	Time synchronization of each circuit-breaker carried out by system	■	■	■	■	■	■
Events	State changes of CB, protections and alarms (the latest 80)	■	■	■	■	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document:
Modbus system Interface for Protection relays PR122/P and PR123/P + communication module PR120/D-M, mounted on CB New Emax
Protection relays PR332/P and PR333/P + communication module PR330/D-M, mounted on CB Emax X1, Tmax T7 and Tmax T8 (document code: 1SDH000556R0001).

Test isolated: position in which the power contacts are disconnected, whereas the auxiliary contacts are connected.

Supervision with fieldbus Modbus RTU

Table A.1A: Measures-data-alarms and commands available with air circuit-breakers type Emax DC

		Emax DC	
		PR122/DC + PR120/D-M	PR123/DC + PR120/D-M
Electrical quantities	Plant current	■	■
	Earth fault current		■
	Voltage		■
	Total active power		■
	Active energy (positive/negative)		■
	Total active energy		■
	Measures history (Imax)	■	■
	Measures history (Vmax, Pmax, Pmean)	■	■
	Data logger	■	■
State information	CB state (open/close/tripped)	■	■
	CB position (connected/test isolated)	■	■
	Spring state (charged/discharged)	■	■
	Mode (local, remote)	■	■
	Protection parameters set, load control parameters	■	■
Maintenance data	Total number of operations (from close to open)	■	■
	Total number of protection trips	■	■
	Total number of trip tests	■	■
	Number of manual operations (with opening command)	■	■
	Number of trips according to each protection functions	■	■
	Contact wear (%)	■	■
	Data recording of the latest 20 trips	■	■
Protection alarms	Protection L (timing and trip)	■	■
	L pre-alarm	■	■
	Protection S (timing and trip)	■	■
	Protection I (trip)	■	■
	Protection against overtemperature OT (pre-alarm and trip)	■	■
	Protection G (timing and trip)		■
	Phase unbalance protection U (timing and trip)		■
	Undervoltage protection UV (timing and trip)		■
	Overvoltage protection OV (timing and trip)		■
	Reverse power protection RP (timing and trip)		■
Diagnostic alarms	Failure of opening mechanism (TRIP command failed)	■	■
	Contact wear = 100%	■	■
	Rating Plug disconnected	■	■
	Trip coil (TC) disconnected or failed	■	■
Controls	CB opening/closing command	■	■
	Reset alarms (Trip reset)	■	■
	Protection curve and threshold settings	■	■
	System time synchronization of each CB	■	■
Events	State changes of CB, protections and alarms (the latest 80)	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document:
Emax DC PR122DC-PR123DC + PR120/D-M Modbus System Interface (document code: 1SDH000841R0001).

Test isolated: position in which the power contacts are disconnected, whereas the auxiliary contacts are connected.

Supervision with fieldbus Modbus RTU

Table A.1B: Measures-data-alarms and commands available with air circuit-breakers type Emax VF

		Emax VF
		PR122/VF + PR120/D-M
Electrical quantities	Phase currents (IL1-IL2-IL3)	■
	Measures history (phase at maximum current-Imax)	■
	Data logger	■
State information	CB state (open/close/tripped)	■
	CB position (connected/test isolated)	■
	Spring state (charged/discharged)	■
	Mode (local, remote)	■
	Protection parameters set, load control parameters	■
Maintenance data	Total number of operations (from close to open)	■
	Total number of protection trips	■
	Total number of trip tests	■
	Number of manual operations (with opening command)	■
	Number of trips according to each protection functions	■
	Contact wear (%)	■
	Data recording of the latest 20 trips	■
Protection alarms	Protection L (timing and trip)	■
	Pre-alarm protection L	■
	Protection I (trip)	■
	Protection against overtemperature OT (pre-alarm and trip)	■
Diagnostic alarms	Failure of opening mechanism (TRIP command failed)	■
	Contact wear = 100%	■
	Rating Plug disconnected	■
	Trip coil (TC) disconnected or failed	■
Controls	CB opening/closing command	■
	Reset alarms (Trip reset)	■
	Protection curve and threshold settings	■
	System time synchronization of each CB	■
Events	State changes of CB, protections and alarms (the latest 80)	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document: Emax VF PR122/VF + PR120/D-M Modbus System Interface (document code: 1SDH000922R0001)

Test isolated: position in which the power contacts are disconnected, whereas the auxiliary contacts are connected.

Supervision with fieldbus Modbus RTU

Table A.2: Measures-data-alarms and commands available with Tmax moulded-case circuit-breakers type T4, T5 and T6

		PR222DS/PD	PR223EF	PR223EF + VM210	PR223DS	PR223DS + VM210
Electric quantities	Phase currents (IL1, IL2, IL3), neutral current (IN), ground current (Ig)	■	■	■	■	■
	Phase-to-phase voltages (V12-V23-V31)			■		■
	Phase-to-neutral voltages (V1-V2-V3)			■		■
	Peak factor (L1-L2-L3-N)		■	■	■	■
	Frequency			■		■
	Total and phase power (active P, reactive Q, apparent S)					■
	Total power factor					■
	Total energy (active, reactive, apparent)					■
State information	Circuit-breaker state (open, closed, tripped)	■	■	■	■	■
	Mode (local, remote)	■	■	■	■	■
	Protection parameters set	■	■	■	■	■
Maintenance data	Total number of operations	■	■	■	■	■
	Total number of trips	■	■	■	■	■
	Number of test trips	■	■	■	■	■
	Number of manual operations	■	■	■	■	■
	Number of trips separated according to the protection functions L-S-I-G	■	■	■	■	■
	Number of trips separated according to the protection functions EF-SOS		■	■		
	Data records of the last n trips	1	20	20	20	20
Protections alarms	Protection I (trip)	■	■	■	■	■
	Protection L, S, G (timing and trip)	■	■	■	■	■
	Protection EF, SOS (trip)		■	■		
Diagnostic alarms	Trip command failed	■	■	■	■	■
	MOE-E overheating	■	■	■	■	■
	Trip coil disconnected or damaged		■	■	■	■
Commands	Circuit-breaker opening/closing (with MOE-E)	■	■	■	■	■
	Alarms reset	■	■	■	■	■
	Circuit-breaker reset (with MOE-E)	■	■	■	■	■
	Setting of protection curves and thresholds	■	■	■	■	■
Events	State changes of CB, of protections and of all alarms	■	■	■	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document:
- Instruction manual PR223EF Modbus System Interface (document code: 1SDH000566R0001)
- Instruction manual PR223DS Modbus System Interface (document code: 1SDH000658R0001)
- Instruction manual PR222DS/PD Modbus System Interface (document code: 1SDH000600R0001).

Supervision with fieldbus Modbus RTU

Table A.3: Measures-data-alarms and commands available with moulded-case circuit-breakers type SACE Tmax XT2-XT4

Electrical quantities (run time values)	Phase currents (I_{L1}-I_{L2}-I_{L3})
	Neutral current (I_{Ne}) (1)
	Ground current (I_g)
	Phase-to-phase voltages (V_{12}-V_{23}-V_{31})
	Phase-neutral voltages (V_{1N}-V_{2N}-V_{3N}) (3)
	Frequency
	Total active power (P_{tot}) and phase power (P_1, P_2, P_3)(3)
	Total reactive power (Q_{tot}) and phase power (Q_1, Q_2, Q_3)(3)
	Total apparent power (S_{tot}) and phase power (S_1, S_2, S_3)(3)
	Active energy (positive/negative)
	Total active energy
	Reactive energy (positive/negative)
	Total reactive energy
	Total apparent energy
	Total power factor ($\cos_{\varphi tot}$) and phase factor ($\cos_{\varphi 1}$, $\cos_{\varphi 2}$, $\cos_{\varphi 3}$) (3)
Electrical quantities (values on demand)(4)	Harmonic analysis in the phases and in the neutral (spectrum of current up to 11th harmonic at 50 Hz and 60 Hz)
	THDi in the phases (L1, L2, L3) and in the neutral (Ne) at 50 Hz and 60 Hz
Measure history	Phase currents (I_{L1max}, I_{L2max}, I_{L3max}, I_{L1min}, I_{L2min}, I_{L3min})
	Neutral current (I_{Nemax}, I_{Nemin}) (1)
	Phase-to-phase voltages (V_{12max}, V_{23max}, V_{31max}, V_{12min}, V_{23min}, V_{31min})
	Phase-neutral voltages (V_{1Nmax}, V_{2Nmax}, V_{3Nmax}, V_{1Nmin}, V_{2Nmin}, V_{3Nmin}) (3)
	Frequency (maximum value, minimum value)
	Total active power (P_{totmax}, P_{totmin}) and phase power (P_{1max}, P_{2max}, P_{3max}, P_{1min}, P_{2min}, P_{3min})(3)
	Total reactive power (Q_{totmax}, Q_{totmin}) and phase power (Q_{1max}, Q_{2max}, Q_{3max}, Q_{1min}, Q_{2min}, Q_{3min})(3)
	Total apparent power (S_{totmax}, S_{totmin}) and phase power (S_{1max}, S_{2max}, S_{3max}, S_{1min}, S_{2min}, S_{3min})(3)
State information	CB state (open/close, tripped)
	CB reset position
	Mode (local, remote)
	Protection parameter setting (curves, times and thresholds)
	Thermal memory activated
Maintenance data	Total number of operations (from closed to open)
	Total number of trips due to protections
	Number of trip tests
	Number of operations (from closed to open) with opening command
	Number of trips failed
	Record data of the latest 20 trips
Protection alarms	Protection I (trip)
	Protection S (timing and trip)
	Protection L (timing and trip)
	Protection G (timing and trip)
	Protection R (rotor blocked) and U (unbalance and phase current loss) (timing and trip)
	Pre-alarm protection L (5)
	Undervoltage protection UV (timing and trip)
	Overvoltage protection OV (timing and trip)
Diagnostic alarms	Trip command failed
	Trip coil disconnected or failed
Commands/Configurations	CB open/close (with MOE-E motor operator)
	CB reset (with MOE-E motor operator)
	Reset alarms (Trip reset)
	Trip test
	Protection parameter setting (curves, times and thresholds)
	Neutral configuration (ON/OFF - 50%/100% of phases)
	Thermal memory enabling/disabling
	Rated voltage setting
Run Time events	State changes of CB, of protections and of all alarms

1) Measurements available with neutral connected (with four-pole CB or three-pole CB + CT for external neutral conductor)
2) Only with Ekip LSIG trip unit
3) Measurements available with neutral connected (with four-pole CB or three-pole CB + external neutral conductor)
4) Available information upon request by sending a command
5) It signals that 90%I1 < I < 120%I1

	XT4			
		XT2		
	Ekip E-LSIG + Ekip Com	Ekip LSI + Ekip Com Ekip LSIG + Ekip Com	Ekip M-LRIU + Ekip Com	Ekip LS/I + Ekip Com TMD/TMA + Ekip Com
	■	■	■	
	■	■		
	■	■ (2)	■	
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■			
	■	■	■	■
	■	■	■	
	■	■		
	■	■	■	
		■	■	
	■	■	■	
	■	■	■	
	■	■	■	
	■	■	■	
	■	■	■	
	■	■	■	
	■	■	■	
	■	■		
	■	■	■	
	■	■ (2)	■	
			■	
	■	■	■	
	■			
	■			
	■	■	■	
	■	■	■	
	■	■	■	■
	■	■	■	■
	■	■	■	
	■	■	■	
	■	■	■	
	■	■		
		■	■	
	■			
	■	■	■	

Supervision with fieldbus Profibus DP and DeviceNet

Table A.4: Measures-data-alarms and commands available with Emax air circuit-breakers, X1 air circuit-breakers and Tmax T7 moulded-case circuit-breakers

		E1÷E6			T7-X1		X1
		PR122/P+ PR120/D-M+ EP010	PR122/P+ PR120/D-M+ PR120/V+ EP010	PR123/P+ PR120/D-M+ EP010	PR332/P+ PR330/D-M+ EP010	PR332/P+ PR330/D-M+ PR330/V+ EP010	PR333/P+ PR330/D-M+ EP010
Electric quantities	Phase currents (IL1, IL2, IL3), neutral current (IN), ground current	■	■	■	■	■	■
	Voltages (phase-to-phase, phase-to-neutral, residual)		■	■		■	■
	Total power (active P, reactive Q, apparent A)		■	■		■	■
	Total power factor		■	■		■	■
	Frequency		■	■		■	■
	Total energy (active, reactive, apparent)		■	■		■	■
	Harmonic analysis (THDi, THDv and spectrum) up to 25th harmonic (odd order harmonics)			■			■
State information	Circuit-breaker state (open, closed, tripped)	■	■	■	■	■	■
	Circuit-breaker position (racked-in/test isolated)	■	■	■	■	■	■
	Spring state (charged, discharged)	■	■	■	■	■	■
	Mode (local, remote)	■	■	■	■	■	■
	Protection parameters set	■	■	■	■	■	■
Maintenance data	Total number of operations	■	■	■	■	■	■
	Total number of trips	■	■	■	■	■	■
Protections alarms	Protection L	■	■	■	■	■	■
	Protection S	■	■	■	■	■	■
	Protection I	■	■	■	■	■	■
	Protection G	■	■	■	■	■	■
	Protection against unbalanced phase currents U (timing and trip)	■	■	■	■	■	■
	Protection against overtemperature of the trip unit OT	■	■	■	■	■	■
	Protection against unbalanced phase voltages U (timing and trip)		■	■		■	■
	Protection against undervoltage UV (timing and trip)		■	■		■	■
	Protection against overvoltage OV (timing and trip)		■	■		■	■
	Protection against residual voltage RV (timing and trip)		■	■		■	■
	Protection against reversal of active power RP (timing and trip)		■	■		■	■
	Protection against under-frequency UF (timing and trip)		■	■		■	■
	Protection against over-frequency OF (timing and trip)		■	■		■	■
	Directional protection D (timing and trip)			■			■
Diagnostic alarms	Trip command failed	■	■	■	■	■	■
	Contact wear = 100%	■	■	■	■	■	■
	Rating Plug error	■	■	■	■	■	■
	Trip coil (TC) disconnected or damaged	■	■	■	■	■	■
	Current sensors disconnected	■	■	■	■	■	■
Commands	Circuit-breaker opening / closing	■	■	■	■	■	■
	Alarm reset (trip reset)	■	■	■	■	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document: Modbus/FBP Interface - User and Operator Manual (document code: 1SDH000510R0001).

Test isolated: position in which the power contacts are disconnected, whereas the auxiliary contacts are connected

Supervision with fieldbus Profibus DP and DeviceNet

Table A.5: Measures-data-alarms and commands available with Tmax moulded-case circuit-breakers type T4, T5 and T6

		PR222DS/PD + EP010	PR223EF + EP010	PR223EF + VM210 + EP010
Electric quantities	Phase currents (IL1, IL2, IL3), neutral current (IN), ground current (Ig)	■	■	■
	Phase-to-phase voltages (V12-V23-V31)			■
	Phase-to-neutral voltages (V1-V2-V3)			■
	Peak factor (L1-L2-L3-N)		■	■
	Frequency			■
State information	Circuit-breaker state (open, closed, tripped)	■	■	■
	Mode (local, remote)	■	■	■
	Protection parameters set	■	■	■
Maintenance data	Total number of operations	■	■	■
	Total number of trips	■	■	■
	Number of trips separated according to the protection function L-S-I-G	■	■	■
	Number of trips separated according to the protection function EF-SOS		■	■
	Number of test trips		■	■
	Number of manual operations		■	■
Protections alarms	Protection L (timing and trip)	■	■	■
	Protection S (timing and trip)	■	■	■
	Protection G (timing and trip)	■	■	■
	Protection I	■	■	■
	Protection EF, SOS		■	■
Diagnostic alarms	Trip command failed	■	■	■
	MOE-E overheating	■	■	■
	Trip coil disconnected or damaged		■	■
Commands	Circuit-breaker opening/closing (with MOE-E)	■	■	■
	Circuit-breaker reset (with MOE-E)	■	■	■
	Alarm reset	■	■	■
Events	State changes of CB, of protections and of all alarms	■	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document: Modbus/FBP Interface - User and Operator Manual (document code: 1SDH000510R0001).

Supervision with fieldbus Profibus DP and DeviceNet

Table A.6: Measures-data-alarms and commands available with moulded-case circuit-breakers type SACE Tmax XT2-XT4

		Ekip LSI + Ekip Com + EP010	Ekip LSIG + Ekip Com + EP010
Electrical quantities	Phase currents (IL1, IL2, IL3)	■	■
	Neutral current (INe) (1)	■	■
	Ground current (Ig)		■
State information	CB state (open/closed)	■	■
	CB state (tripped)	■	■
	CB state (reset)	■	■
	Mode (local, remote)	■	■
	Protection parameters set (curves and thresholds of protections)	■	■
	Thermal memory activated	■	■
Maintenance data	Total number of operations	■	■
	Total numbers of trips due to protections	■	■
	Number of trip test	■	■
	Number of manual operations with opening command	■	■
	Number of trips failed	■	■
	Record data of the latest 15 trips	■	■
Protection alarms	Protection I (trip)	■	■
	Protection S (timing and trip)	■	■
	Protection L (timing and trip)	■	■
	Protection G (timing and trip)		■
	Pre-alarm protection L (2)	■	■
Diagnostic alarms	Trip command failes	■	■
	Trip coil disconnected or failed	■	■
Commands	CB open/close (with MOE-E motor operator)	■	■
	CB reset (with MOE-E motor operator)	■	■
	Reset alarms (Trip reset)	■	■
	Trip test	■	■
Run Time events	State changes of CB, of protections and of all alarms	■	■

(1) Measurement available with neutral connected (with four-pole CB or three-pole CB + CT for external neutral conductor)
(2) It signals that: 90%I1 < I < 120%I1

Annex B: Electrical characteristics of the auxiliary power supply

The auxiliary supply must be provided from the outside, using a galvanically isolated power supply. Since an auxiliary voltage isolated from the ground is required, it is necessary to use "galvanically isolated converters", complying with the Std. IEC 60950 (UL 1950) or its equivalent Stds. (IEC 60364-41 and CEI 64-8) which guarantee a common mode current or leakage current (see Stds. IEC 478/1 and CEI 22/3) not exceeding 3.5 mA.

Air circuit-breakers type Emax E1÷E6, Emax X1 and moulded-case circuit-breakers type Tmax T7-T7M

As regards the air circuit-breakers type Emax, Emax X1 and Tmax T7 moulded-case circuit-breakers, the auxiliary power supply is delivered to the terminal box and precisely to the terminals K1 (for the pole "+" of the power supply) and K2 (for the pole "-" of the power supply).
The electrical characteristics of the auxiliary supply for the each circuit-breaker type is reported in the following tables:

Emax E1÷E6

Electrical characteristics	PR122/P-PR123/P	PR122/DC-PR123/DC	PR122/VF(2)
Rated voltage	24 V dc ± 20%	24 V dc ± 20%	24 V dc ± 20%
Maximum ripple	± 5%	± 5%	± 5%
Inrush current @24V	~ 10 A for 5 ms	~ 10 A for 5 ms	~ 10 A for 5 ms
Rated current @24V	~ 170 mA(1)	-	-
Rated power @24V	4 W(1)	~ 4 W(1)	~ 4 W(1)

(1) Value referred to the supply of the trip unit PR12X/P or PR12X/DC or PR122/VF + PR120/D-M communication module.
(2) For the connection of the auxiliary supply to the trip unit a shielded twisted pair cable (e.g.: cable type BELDEN 3105A/3105B) is to be used. The shield of the cable must be grounded at one end of the connection towards the trip unit.

Emax X1 and Tmax T7-T7M

Electrical characteristics	PR332/P-PR333/P
Rated voltage	24 V dc ± 20%
Maximum ripple	5%
Inrush current @24V	2 A for 5 ms
Rated current @24V	~ 170 mA*
Rated power @24V	4 W*

(*) Value referred to the supply of: PR33X/P + PR330/D-M communication module

Tmax moulded-case circuit-breakers: T4-T5-T6

The electrical characteristics of the auxiliary supply voltage Vaux are shown in the following table:

Electrical characteristics	PR222DS/PD	PR223DS PR223EF
Rated voltage	24 V dc ± 20%	24 V dc ± 20%
Maximum ripple	± 5%	± 5%
Inrush current @24V	1 A for 30 ms	~ 4 A for 0.5 ms
Rated current @24V	100 mA	~ 80 mA
Rated power @24V	2.5 W	~ 2 W

As for the moulded-case circuit-breakers type Tmax T4, T5 and T6, the auxiliary supply is provided to the trip units PR222DS/PD, PR223EF and PR223DS through the terminals 3 and 4 of X3 rear connector as shown in the following figure:

Figure B.1: Wiring diagram of the auxiliary power supply connection for P223DS trip unit.

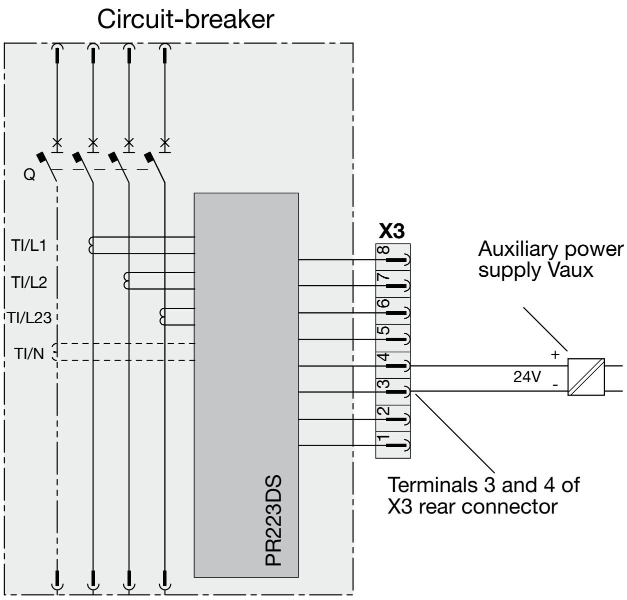
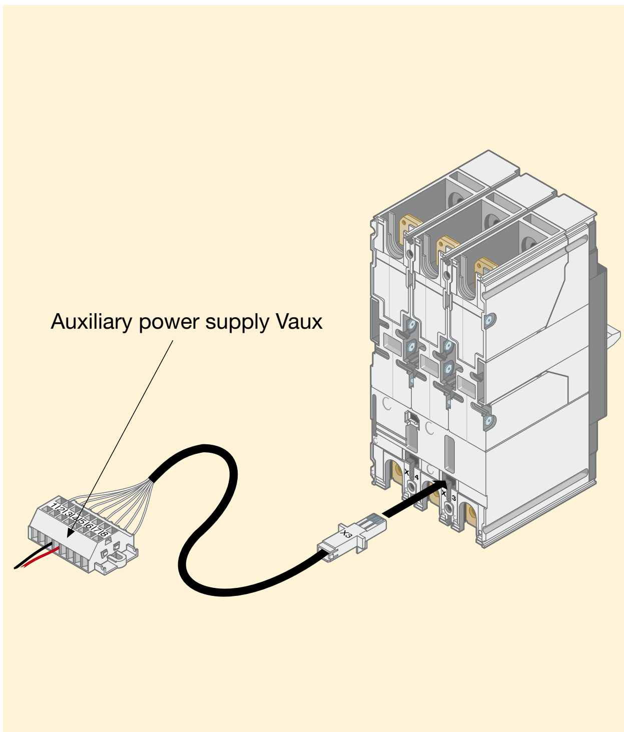


Figure B.2: Auxiliary power supply for moulded-case circuit-breakers T4, T5 and T6



Moulded-case circuit-breakers: SACE Tmax XT2 - XT4

The auxiliary supply for the moulded-case circuit-breakers SACE Tmax XT2 and XT4 is delivered to the Ekip Com module and to the electronic trip unit through the cables marked with K1 (from the pole "+" of the power supply) and K2 (from the pole "–" of the power supply). The electrical characteristics of the auxiliary supply voltage Vaux are shown in the following table:

Electrical characteristics	Ekip LSI/LSIG Ekip E-LSIG Ekip M-LRIU	Ekip Com
Rated voltage	24V dc ± 20%	24V dc ± 20%
Maximum ripple	± 5%	± 10%
Inrush current @24V	500 mA for 20 ms	1 A for 0.05 ms
Rated current @24V	20 mA	22 mA ± 20%
Rated power @24V	480 mW	530 mW

When the electronic trip unit is used with Ekip Com communication module, the power and current data are summed.

Annex C: The communication modules

Emax air circuit-breakers E1÷ E6

- PR120/D-M communication module

Protocol	Modbus RTU
Physical interface	RS-485
Baud rate	9600-19200 bit/s

The communication module is supplied directly through PR122/P/DC/VF-PR123/P/DC trip unit, which in its turn is supplied by the auxiliary power supply Vaux. The relevant technical data are shown in the following table.

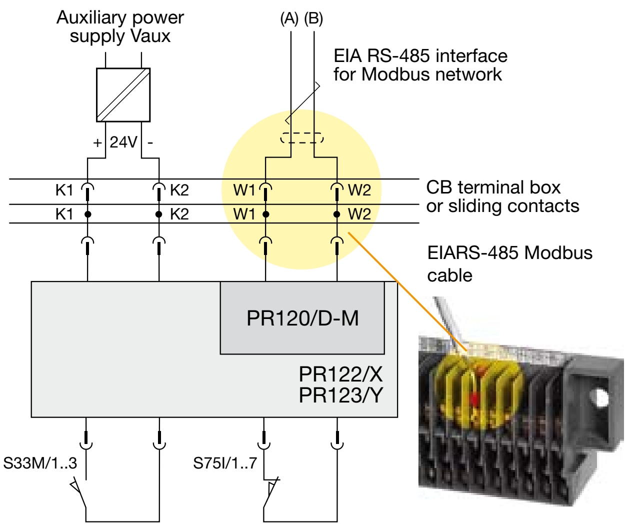
	PR122*/PR123	PR120/D-M
Supply (galvanic insulated)	auxiliary power supply 24 V dc ± 20%	from PR122/PR123
Maximum ripple	5%	-
Inrush current @24 V	~ 10 A for 5 ms	-
Rated current @24 V	~ 130 mA	+ 40 mA
Rated power @24 V	~ 3 W	+ 1 W

(*) With PR122/VF trip unit, for the connection of the auxiliary supply to the trip unit a shielded twisted pair cables (e.g.: cable type BELDEN 3105A/3105B) must be used. The shield must be earthed at the end of the connection towards the trip unit.

- Connection to the Modbus network

PR122/P/DC/VF-PR123/P/DC trip units are connected to the Modbus network through the communication module PR120/D-M according to the diagram in the figure.

Figure C.1: Wiring diagram for the connection of PR12X/P to the Modbus network through PR120/D-M module



Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for auxiliary power supply Vaux
S33M/1..3: contacts signaling spring charged
S75I/1..7: contacts signaling circuit-breaker racked-in (for CBs in withdrawable version)

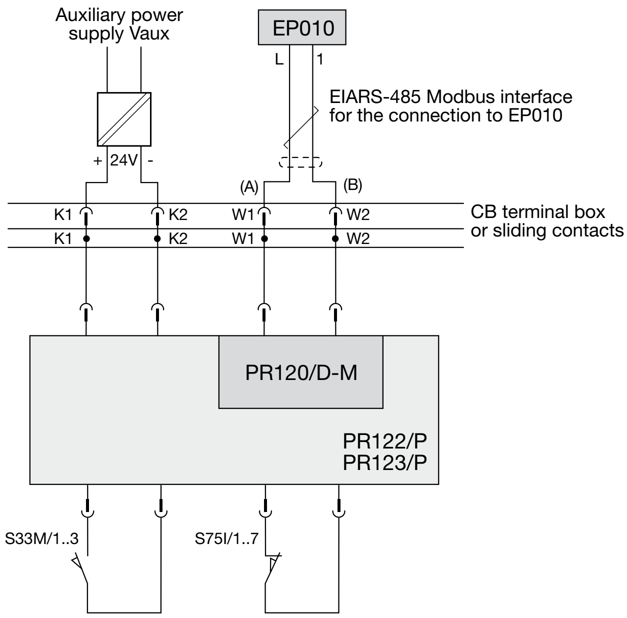
X: P/DC/VF
Y: P/DC
With PR122/VF trip unit, for the connection of the auxiliary supply to the trip unit, a shielded twisted pair cables must be used (e.g.: cable type BELDEN 3105A/3105B). The shield must be earthed at the end of the connection towards the trip unit.

Inside PR120/D-M module there are the contacts K51/YO (to control directly the shunt opening release YO) and K51/YC (to control directly the shunt closing release YC) to carry out the circuit-breaker opening and closing commands from remote.
With PR120/D-M communication module, the supply of the shunt opening and closing releases YO and YC must not be derived from the main supply and can have maximum voltage values equal to:
- 110-120 V DC
or
- 240-250 V AC

- Connection to EP010 unit

PR122/P and PR123/P trip units are connected to EP010 unit through the communication module PR120/D-M.

Figure C.2: Wiring diagram for the connection of PR122/P-PR123/P to EP010 unit



Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for auxiliary power supply Vaux
L-1: terminals for the Modbus port
S33M/1..3: contacts signaling spring charged
S75I/1..7: contacts signaling circuit-breaker racked-in (for CBs in withdrawable version)
The Modbus cable which connects EP010 to the trip unit shall have a maximum length of 1 m.

Emax X1 air circuit-breakers and Tmax T7 moulded-case circuit-breakers

- PR330/D-M communication module

Protocol	Modbus RTU
Physical interface	RS-485
Baud rate	9600-19200 bit/s

The communication module is supplied directly through PR332/P or PR333/P trip unit, which in its turn is supplied by the auxiliary power supply Vaux. The relevant technical data are shown in the following table.

	PR332/PR333	**PR330/D-M**
Supply (galvanic insulated)	auxiliary power supply 24 V dc ± 20%	from PR332/PR333
Maximum ripple	5%	-
Inrush current @24 V	2 A for 5 ms	-
Rated current @24 V	~ 130 mA	+ 40 mA
Rated power @24 V	~ 3 W	+ 1 W

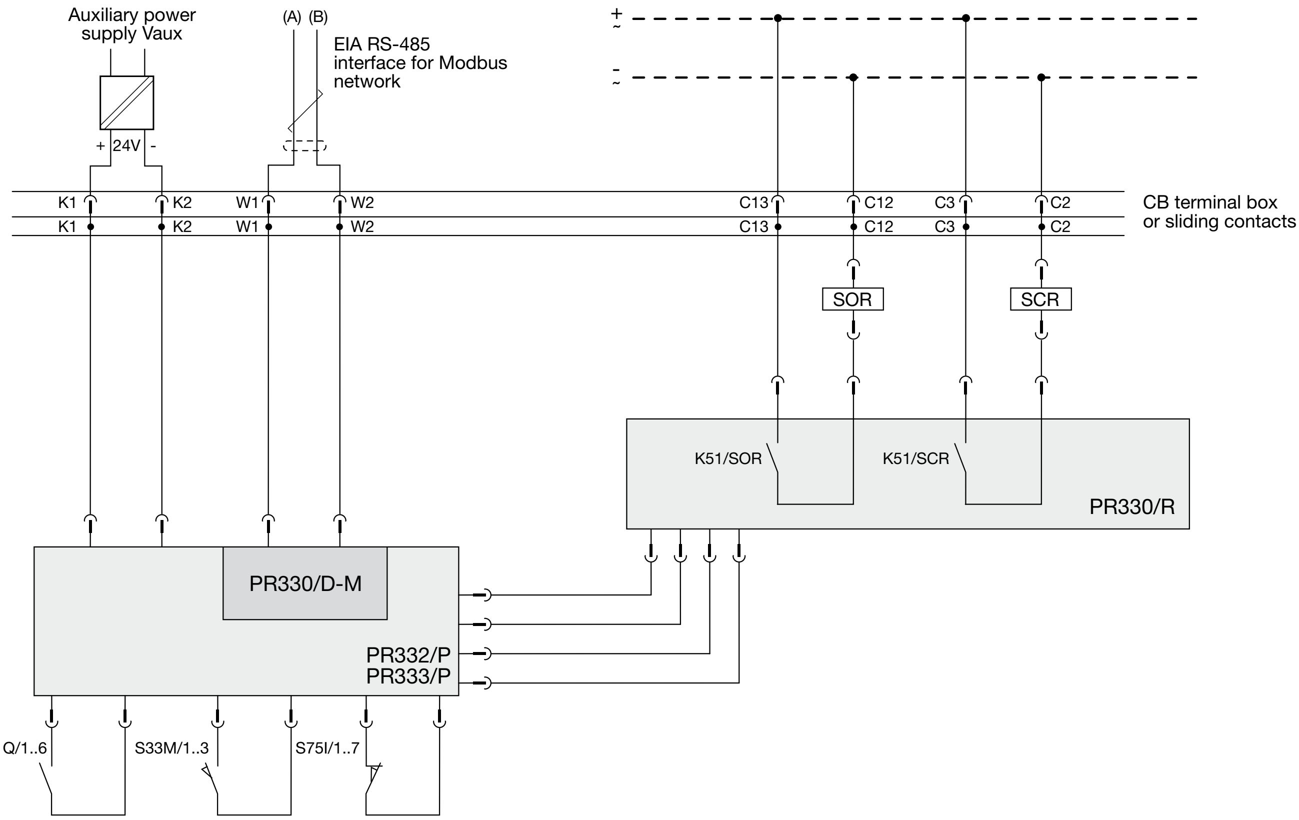
- PR330/R actuator module

Emax X1 and Tmax T7 circuit-breakers can operate opening and closing commands from remote control when, together with PR330/D-M communication module, they are equipped with PR330/R actuator module too.
This device allows such commands to be carried out through the internal contacts K51/SCR (to command the shunt closing release SCR) and K51/SOR (to command the shunt opening release SOR). See Figure C.3.

- Connection to Modbus network

PR332/P and PR333/P trip units are connected to the Modbus network through PR330/D-M communication module according to the diagram in the figure C.3.

Figure C.3: Wiring diagram for the connection of PR33X/P to the Modbus network through PR330/D-M module

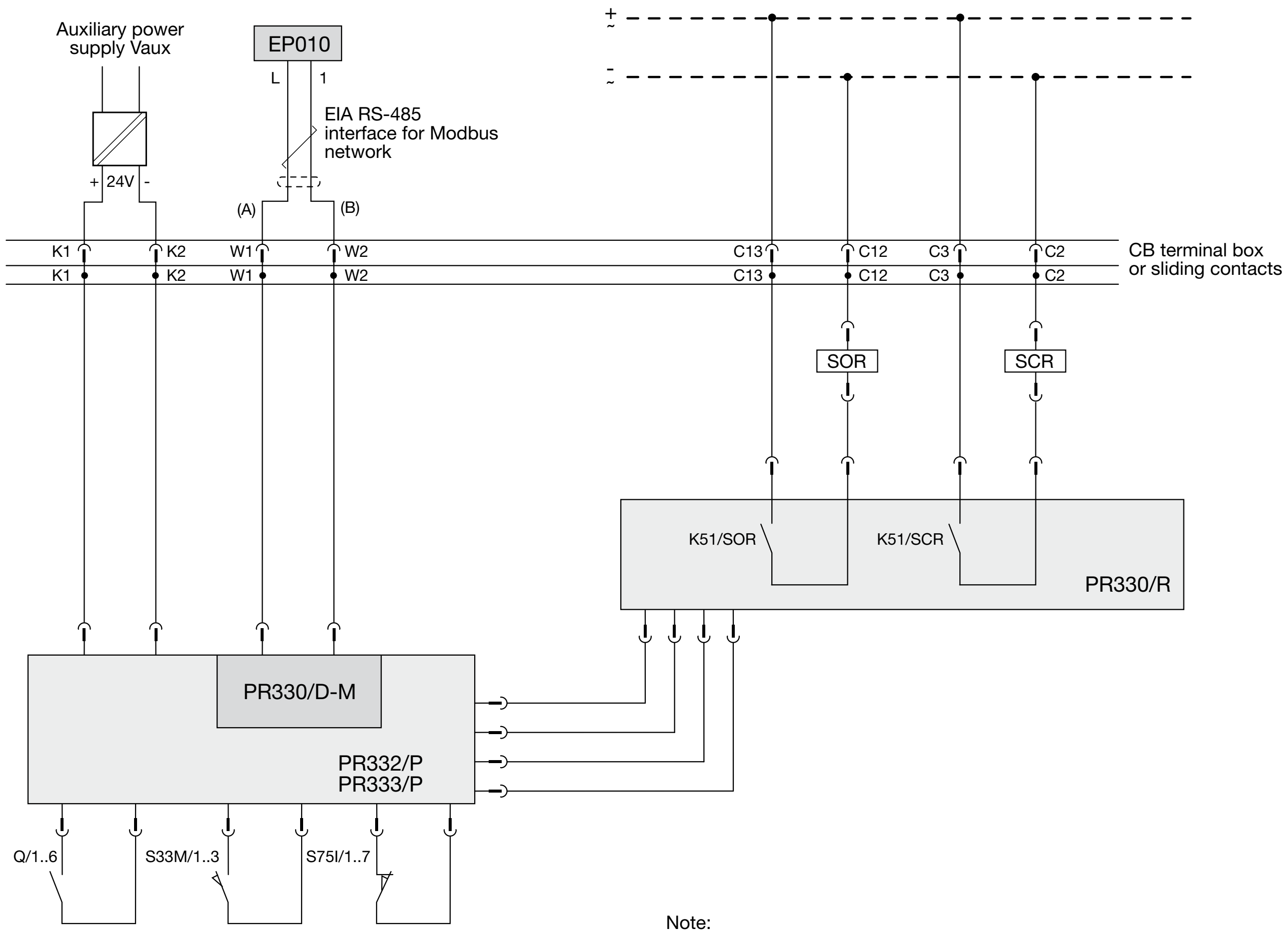


Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for auxiliary power supply (Vaux)
SOR: shunt opening release
SCR: shunt closing release
K51/SOR: control contact for the shunt opening release
K51/SCR: control contact for the shunt closing release
Q/5-Q/6: circuit-breaker auxiliary contacts
S33M/1..3: contacts signaling spring charged
S75I/1..7: contacts signaling circuit-breaker racked-in
(for CBs in withdrawable version)
The supply of the shunt opening release (SOR) and of the shunt closing release (SCR) must not be derived from the main supply and can have maximum voltage values equal to:
- 110-120 V DC
or
- 240-250 V AC

- Connection to EP010 unit

PR332/P and PR333/P trip units are connected to EP010 unit through the communication module PR330/D-M.

Figure C.4: Wiring diagram for the connection of PR33X/P to EP010 unit



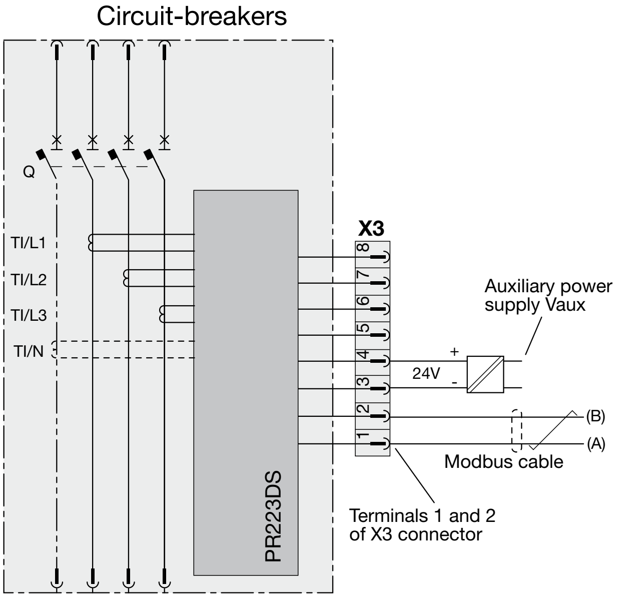
Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for auxiliary power supply (Vaux)
L-1: terminals for the Modbus port
SOR: shunt opening release
SCR: shunt closing release
K51/SOR: control contact for the shunt opening release
K51/SCR: control contact for the shunt closing release
Q/5-Q/6: circuit-breaker auxiliary contacts
S33M/1..3: contacts signaling spring charged
S75I/1..7: contacts signaling circuit-breaker racked-in (for CBs in withdrawable version)
The Modbus cable which connects EP010 to the trip unit shall have a maximum length of 1 m.
The supply of the shunt opening release (SOR) and of the shunt closing release (SCR) must not be derived from the main supply and can have maximum voltage values equal to:
- 110-120 V DC
or
- 240-250 V AC

Tmax moulded-case circuit-breakers type T4-T5-T6

- Connection to the Modbus network

The connection to the Modbus network of the moulded-case circuit-breakers type T4, T5 and T6 equipped with PR222DS/PD, PR223EF and PR223DS trip units is carried out through the terminals 1 and 2 of the dedicated X3 rear connector as shown in the diagram of Figure C.5.

Figure C.5: Wiring diagram for the connection of PR223DS trip unit to the Modbus network through X3 connector



- Connection to EP010 unit

The moulded-case circuit-breakers type T4, T5 and T6, are connected to the unit EP010 through the terminals 1 and 2 of X3 rear connector.

Figure C.7: Wiring diagram for the connection of the unit EP010 of a Tmax circuit-breaker

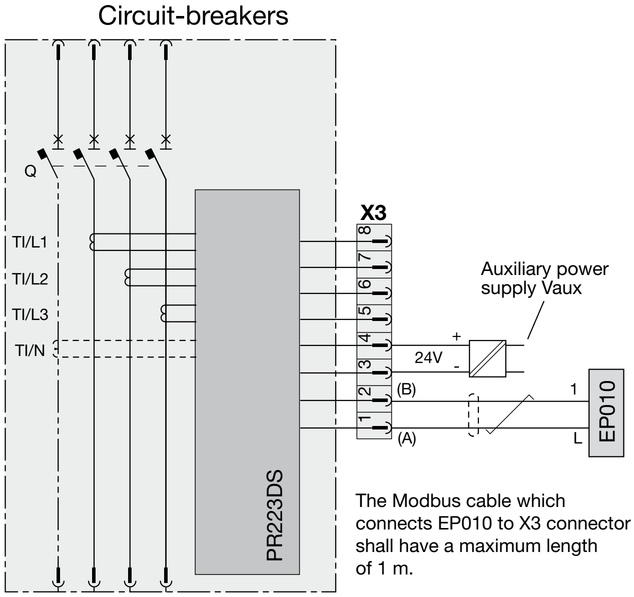
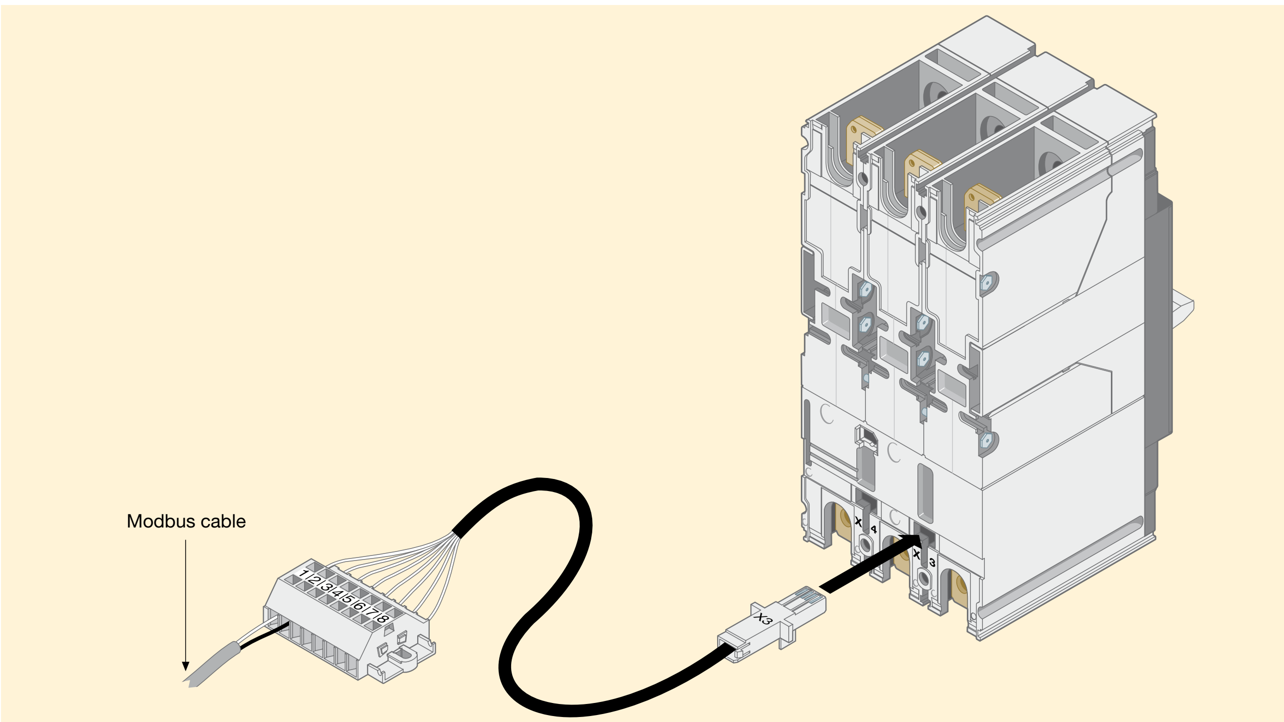


Figure C.6: Connection to the Modbus network of Tmax CBs T4, T5 and T6 through X3 connector



SACE Tmax XT2-XT4 moulded-case circuit-breakers

– Ekip Com communication module

Protocol	Modbus RTU
Physical interface	RS-485
Baud Rate	9600/19200 bit/s

Ekip Com is the communication interface which allows you to:
- connect Ekip electronic trip units, with dialogue function, into the field bus Modbus RTU;
- control via remote MOE-E motor operator with electronic interface;
- detect the state (open/closed/tripped) of the circuit-breaker.

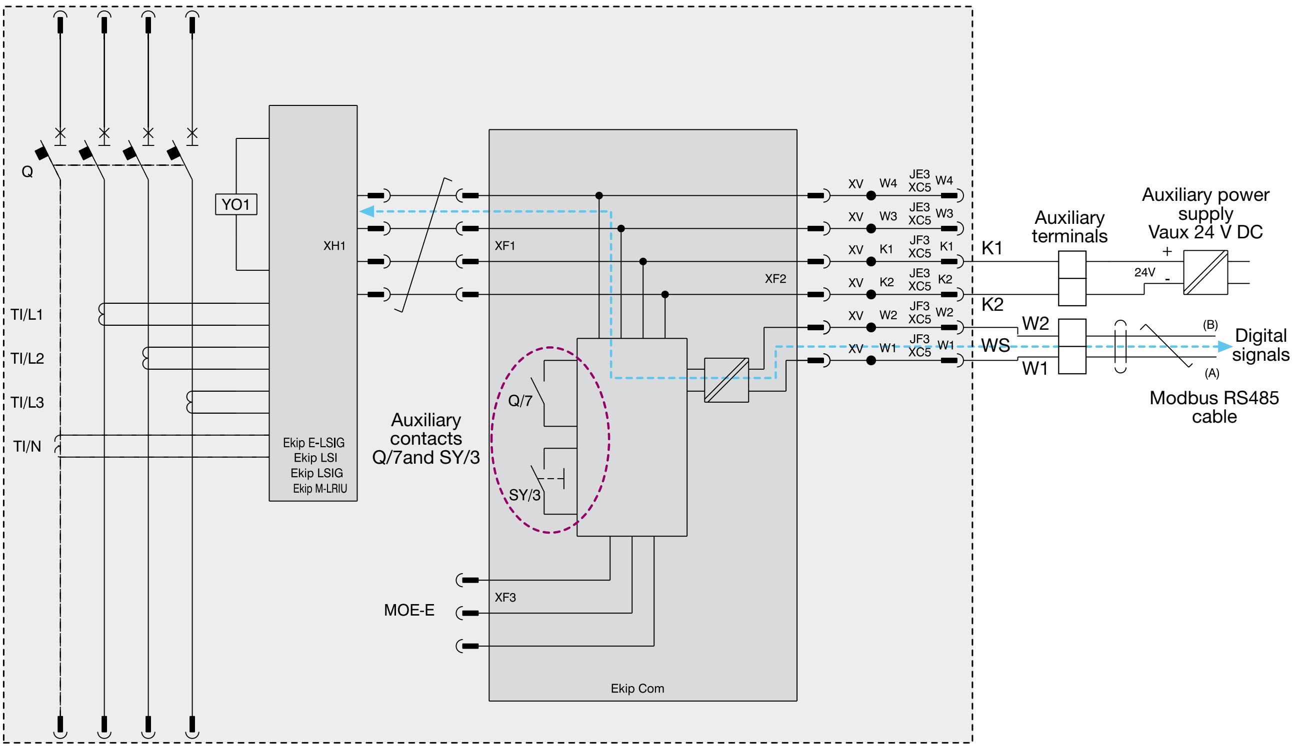
Ekip Com is available in two versions: one for fixed/plug-in circuit-breakers and one for withdrawable circuit-breakers.
For the communication on the Modbus network, an auxiliary voltage (Vaux) up to 24 V DC is necessary to supply the communication module and the electronic trip unit. As regards the electrical characteristics of the auxiliary supply voltage see Annex B.

- Connection to the Modbus network

The electronic trip units type Ekip E-LSIG, Ekip LSI, Ekip LSIG and Ekip M-LRIU are connected to the Modbus network through Ekip Com communication module.
There are also the auxiliary contacts Q/7 and SY/3 built-in inside Ekip Com for electrical signaling of circuit-breaker in open/closed position and for circuit-breaker in tripped position[11] (see Figure C.8) respectively. These contacts make the information about the circuit-breaker state available for the remote supervision system.
With the circuit-breaker in withdrawable version the trip unit is connected to the Modbus network through W1 and W2 cables coming out from the fixed part (the socket) of JF3 connector, housed in the fixed part of the circuit-breaker (see Figures C.8, C.9 and C.10).

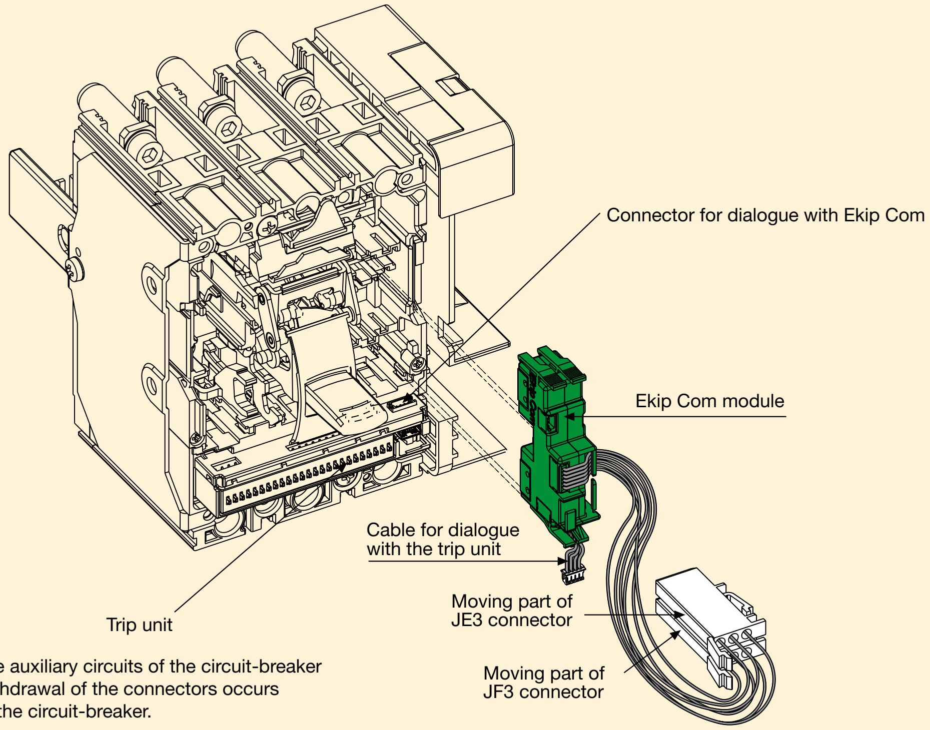
[11] *SY/3: contact for electrical signaling of circuit-breaker open due to tripping of magnetic/thermomagnetic trip units, microprocessor-based trip unit (electronic type), shunt opening release, undervoltage release, residual current release.*

Figure C.8: Wiring diagram for the electrical connection to the Modbus network of the trip units type Ekip E-LSIG, Ekip LSI, Ekip LSIG and Ekip M-LIRU with Ekip Com module. Circuit-breaker in withdrawable version.



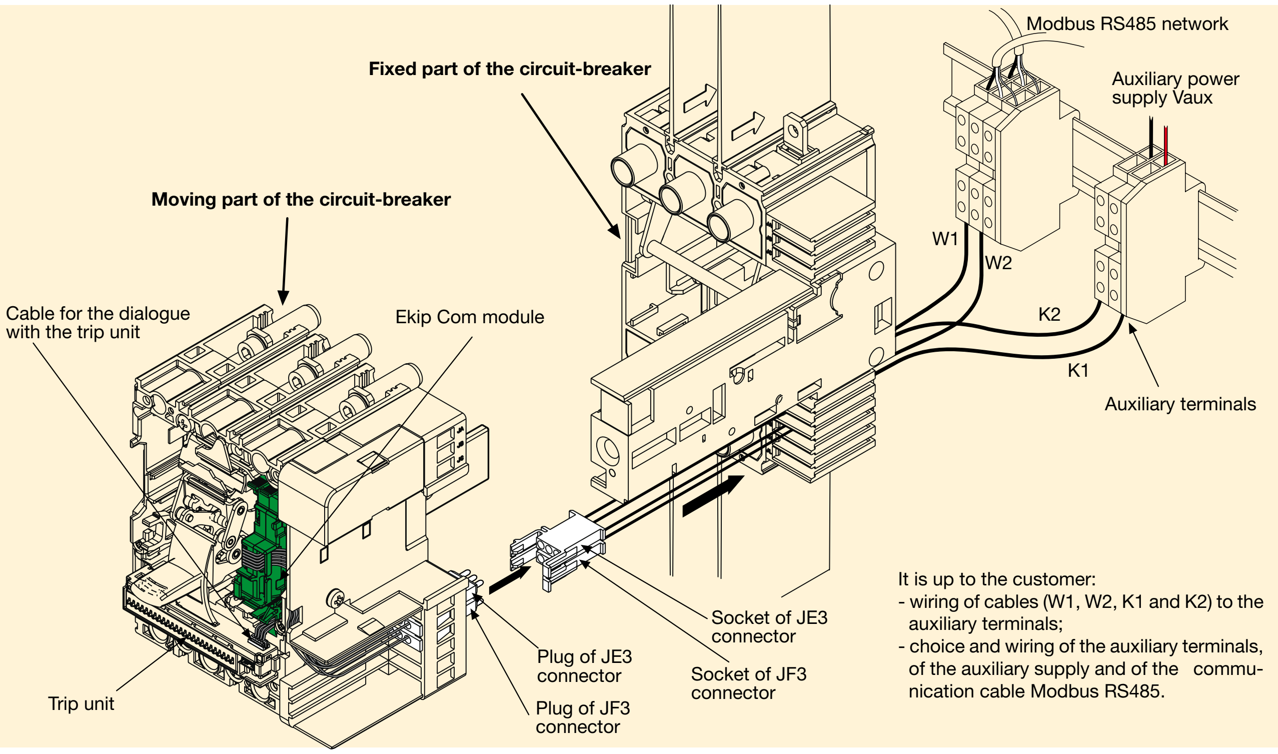
It is up to the customer:
- wiring of cables (W1, W2, K1 and K2) to the auxiliary terminals;
- choice and wiring of the auxiliary terminals, of the auxiliary supply and of the Modbus RS485 communication cable.

Figure C.9: Ekip Com module for SACE Tmax XT2 and XT4 moulded-case circuit breakers in withdrawable version



JE3-JF3: Connectors for the auxiliary circuits of the circuit-breaker in withdrawable version; withdrawal of the connectors occurs simultaneously with that of the circuit-breaker.

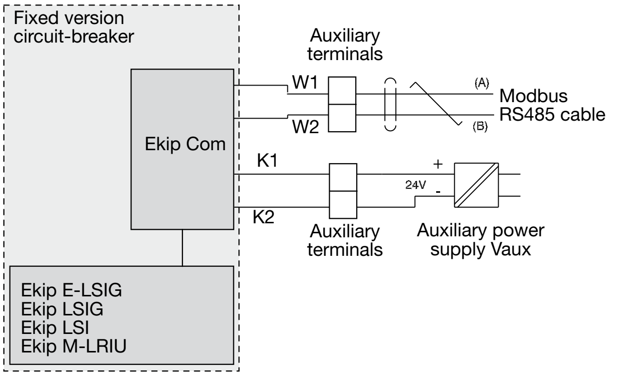
Figure C.10: Connection to the Modbus network of SACE Tmax XT2 and XT4 circuit-breakers in withdrawable version



It is up to the customer:
- wiring of cables (W1, W2, K1 and K2) to the auxiliary terminals;
- choice and wiring of the auxiliary terminals, of the auxiliary supply and of the communication cable Modbus RS485.

When the moving part of the circuit-breaker is inserted in the fixed part, the coupling between the socket (fixed part) of JF3 connector (inserted in the fixed part of the circuit-breaker) and the plug (moving part) of JF3 connector (inserted in the moving part of the circuit-breaker), accomplishes wiring continuity for the connection of the trip unit to the Modbus network. Coupling of the fixed part with the corresponding moving part of JE3 and JF3 connectors accomplishes also wiring continuity to provide the auxiliary supply to Ekip Com module and to the trip unit.

With SACE Tmax XT2-XT4 circuit-breakers in fixed version, the trip unit is connected to the Modbus network through the cables W1 and W2, according to the following diagram:



It is up to the customer:
- wiring of cables (W1, W2, K1 and K2) to the auxiliary terminals;
- choice and wiring of the auxiliary terminals, of the auxiliary supply and of Modbus RS485 cable.

Figure C.11: Ekip Com module for molded-case circuit-breakers SACE Tmax XT2 and XT4 in fixed version

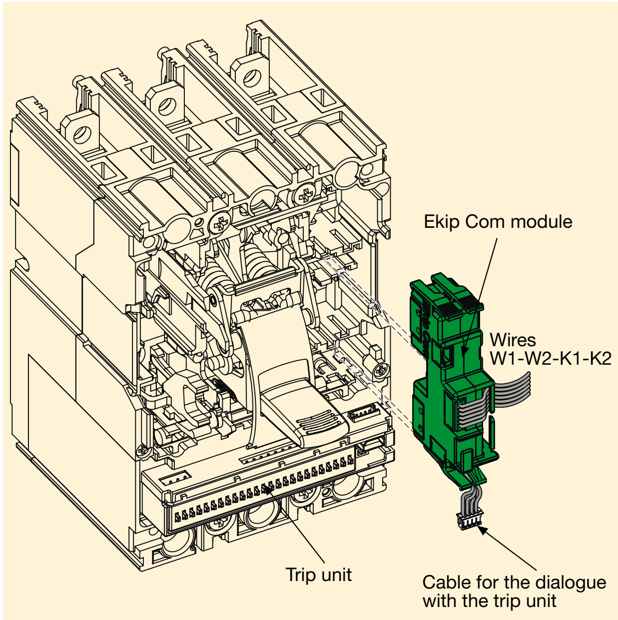
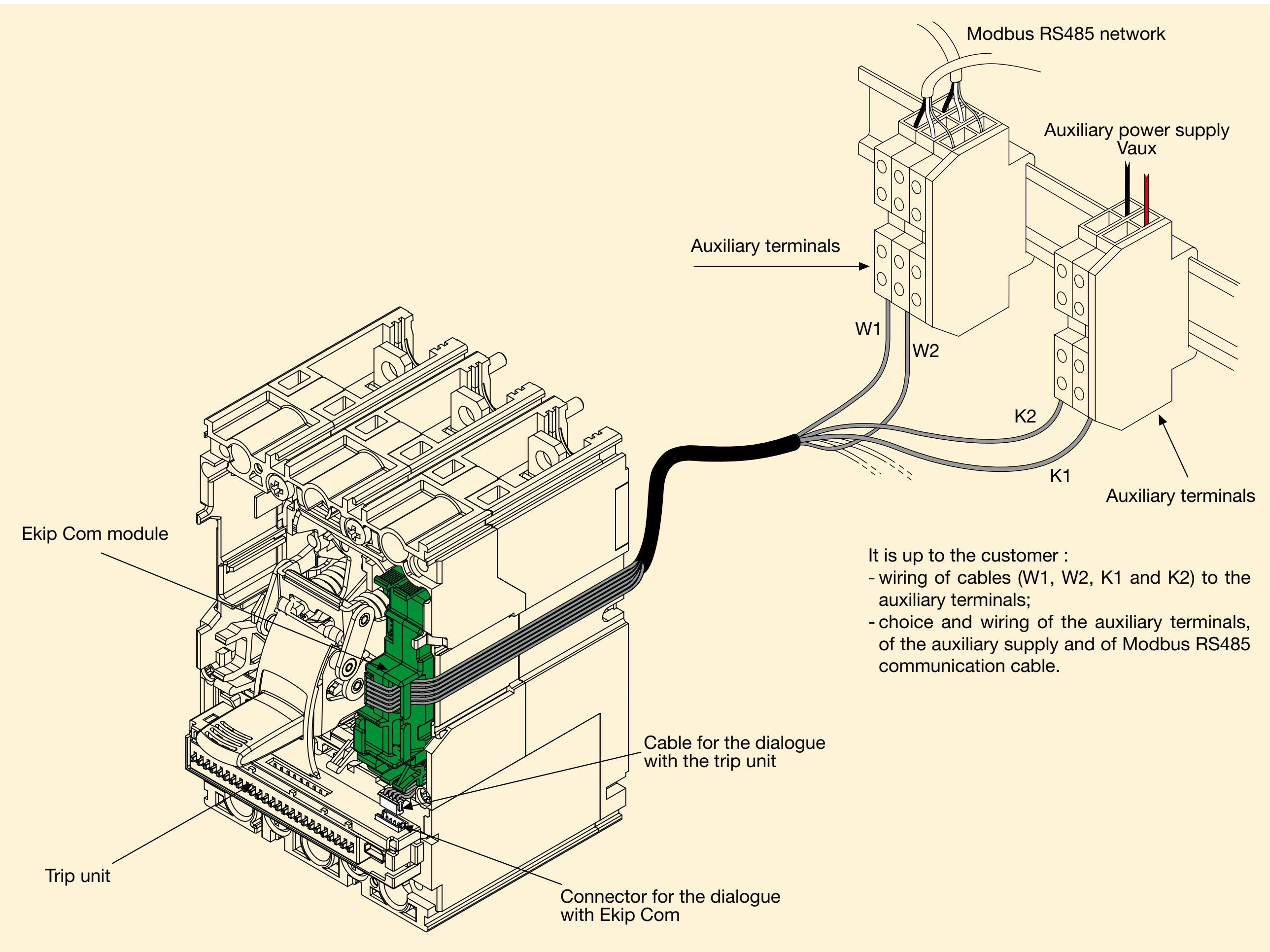
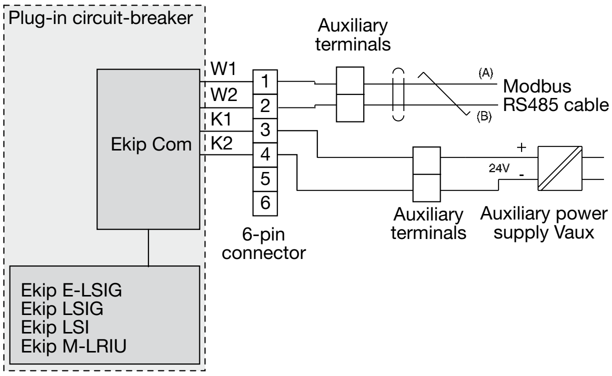


Figure C.12: Connection to the Modbus network of SACE Tmax XT2 and XT4 circuit-breakers in fixed version



It is up to the customer :
- wiring of cables (W1, W2, K1 and K2) to the auxiliary terminals;
- choice and wiring of the auxiliary terminals, of the auxiliary supply and of Modbus RS485 communication cable.

With SACE Tmax XT2-XT4 circuit-breakers in plug-in version, the connection of Ekip electronic trip units with dialogue functions to the Modbus network is carried out through the 6-pin connector (XC5), according to the following diagram:



XC5: 6-pin plug and socket connector on rear of panel for the auxiliary circuits of the circuit-breaker in plug-in version.
It is up to customer:
- wiring of cables (W1, W2, K1 and K2) to XC5 connector;
- choice and wiring of the auxiliary terminals, of the communication cable Modbus RS485 and of the auxiliary supply.

The coupling between the socket (fixed part) of the 6-pin connector and the corresponding plug (moving part) accomplishes the continuity of wiring for the connection of the trip unit to the Modbus network.

- Connection to EP010 unit

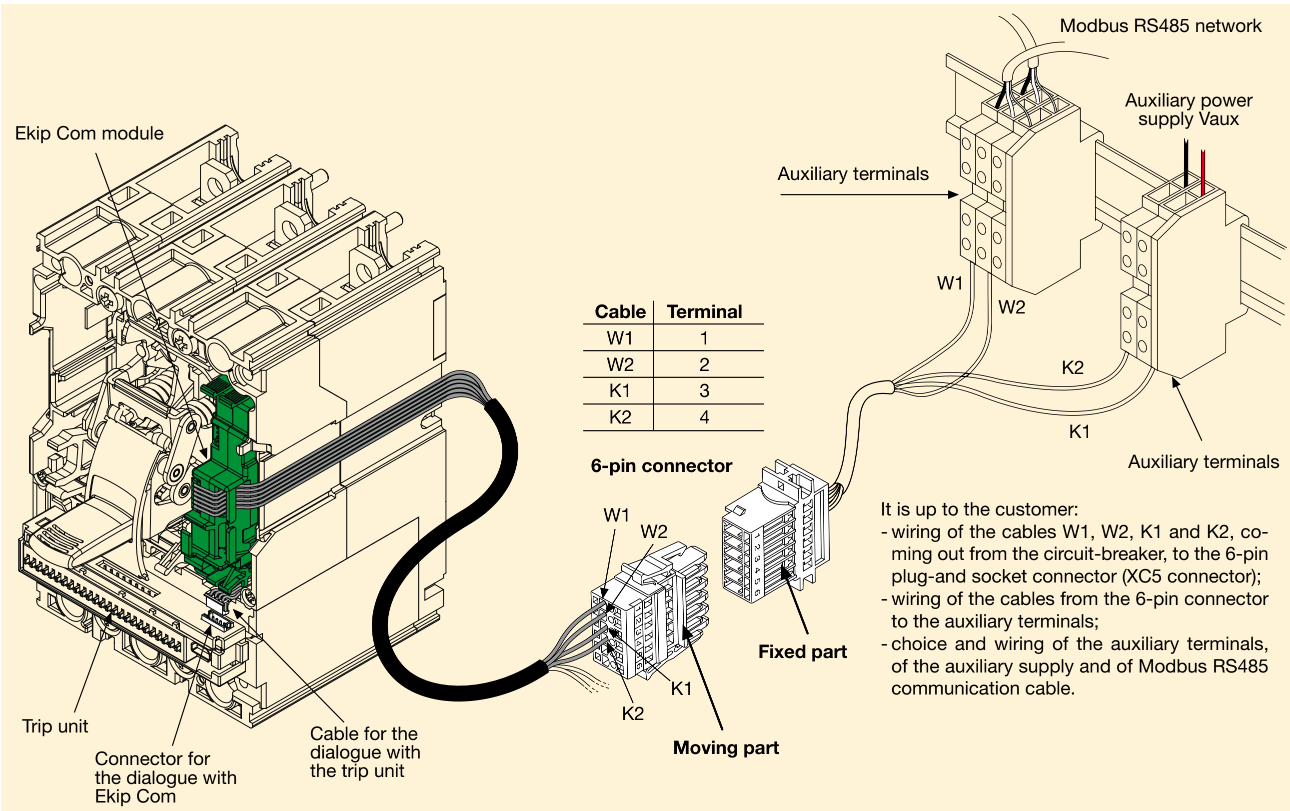
SACE Tmax XT2 and XT4 moulded-case circuit-breakers, equipped with electronic trip units type Ekip LSI and Ekip LSIG, are connected to EP010 unit through:
- the cables W1 and W2 coming out of Ekip Com module installed in the circuit-breaker (with circuit-breaker in fixed version);
- the cables W1 and W2 coming out of the fixed part (the socket), of JF3 connector, housed in the fixed part of the circuit-breaker (with circuit-breaker in withdrawable version)
- the cables coming from the terminals 1 (for W1) and 2 (for W2) of the fixed part (the socket) of the 6-pin plug and socket connector on rear of panel (with circuit-breaker in plug-in version).

The connection between the communication cables/terminals, W1 and W2, of Ekip electronic trip units and the terminals Modbus, L (left) and 1 (right), of EP010 unit, must be carried out as shown in the following table:

Modbus EP010 terminals	Modbus communication cables/terminals of the trip unit
L (left)	W1/A
1 (right)	W2/B

It is up to the customer to connect the trip unit with EP010 and to connect the field bus through the suitable connector FBP (FieldBusPlug).

Figure C.13: Connection to the Modbus network of SACE Tmax XT2 and XT4 circuit-breakers in plug-in version



Annex D: The measuring modules

Emax air circuit-breakers E1 to E6 with PR120/V measuring module and X1 air circuit-breaker and Tmax T7 moulded-case circuit-breaker with PR330/V measuring module

The measuring module has the main function of measuring and processing the phase voltages.
The measured data are transferred to the trip unit, so that a series of electrical parameters (see Annex A) useful for the monitoring of the plant by the supervision system is made available or, if necessary, to allow the implementation of a protection logic for the plant.

Besides, PR120/V and PR330/V measuring modules can give the trip unit an additional supply (without replacing the self supply or the auxiliary power supply, this last always necessary for the communication via bus) respectively to the trip units type PR122/P and PR123/P for Emax E1-E6, PR332/P and PR333/P for Emax X1 and PR332/P for Tmax T7.

Figure D.1: PR120/V measuring module

Figure D.2: PR330/V measuring module

Tmax moulded-case circuit-breakers T4-T5-T6

- Features of VM210 measuring module

VM210 module is a voltage transducer which can be connected directly to the electric network. It provides a graduated output signal to be used by the ABB protection trip units PR223EF and PR223DS.

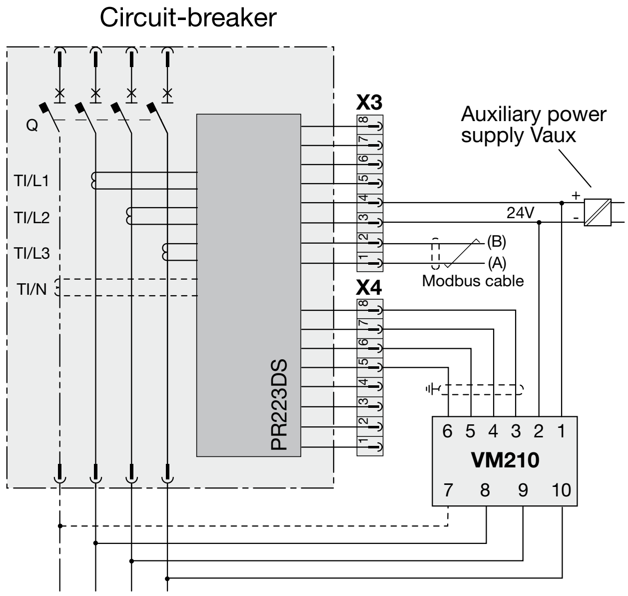
Figure D.3: VM210 measuring module

The output signals on terminals 3, 4, 5 and 6 of VM210, associated with the system voltages, are brought as input to the trip unit through the terminals 5, 6, 7 and 8 of the dedicated X4 connector, according to the wiring diagram of Figure D.4.

In order to operate, VM210 shall be supplied through the terminals 1 and 2 with an auxiliary power supply of 24V dc having the following characteristics:

Supply voltage	24 Vdc ± 20%
Maximum ripple	5%
Rated power @24 V	3.5 W

Figure D.4: Connection of VM210 module to PR223DS trip unit



VM210 Connection table

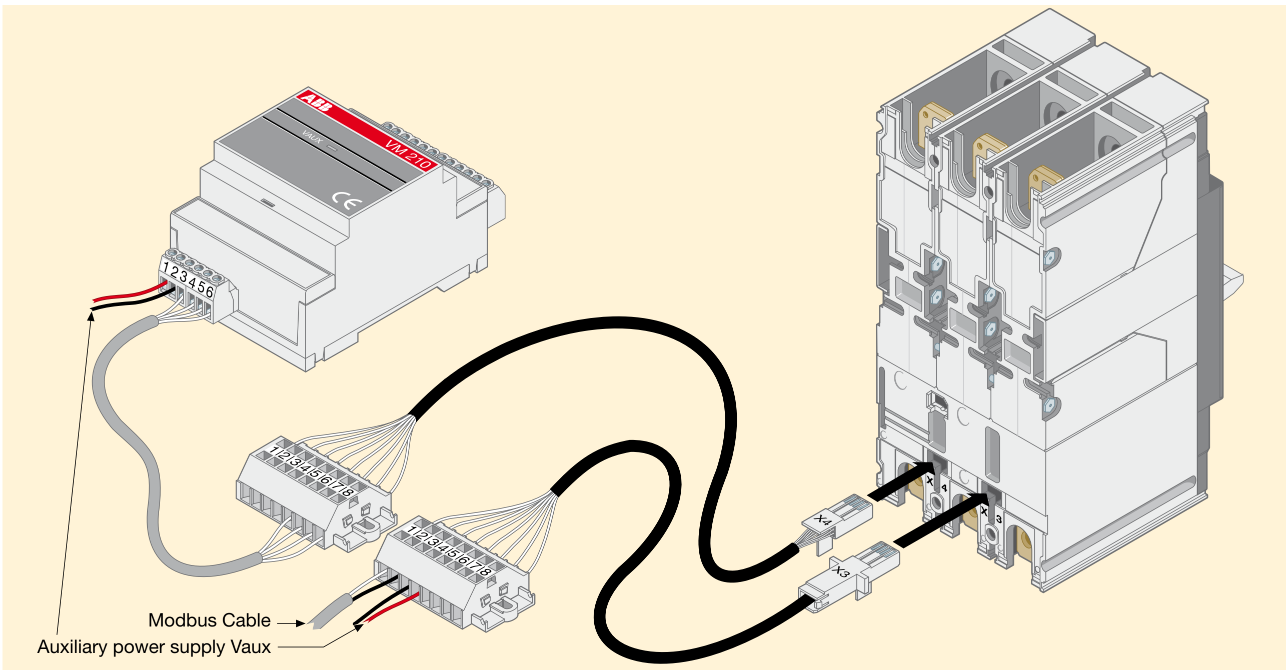
	Terminal	Signal
Input	1	Vaux +
	2	Vaux -
	7	N
	8	L1
	9	L2
	10	L3

	Terminal	Signal
Output	3	COMM
	4	Vout1
	5	Vout2
	6	Vout3

Connections between VM210 and circuit-breaker/trip unit:
- terminals 3 to 6: maximum length of cable 15m (twisted multicore cable, shielded with shield earthed on one side of the connection); cross-sectional area 0.2÷2.5 mm2 (22÷14 AWG)
- terminals 1-2 and 7 to 10: maximum length of cable 15m; cross-sectional area 0.2÷2.5 mm2 (22÷14 AWG)

Maximum number of PR223DS/PR223EF which can be connected to a single VM210: 5

Figure D.5: Connection of VM210 module to X4 connector



Annex E: AUX-E auxiliary contacts and MOE-E motor operator for Tmax T4-T5-T6

For Tmax circuit-breakers type T4, T5 and T6 some special accessories are needed:

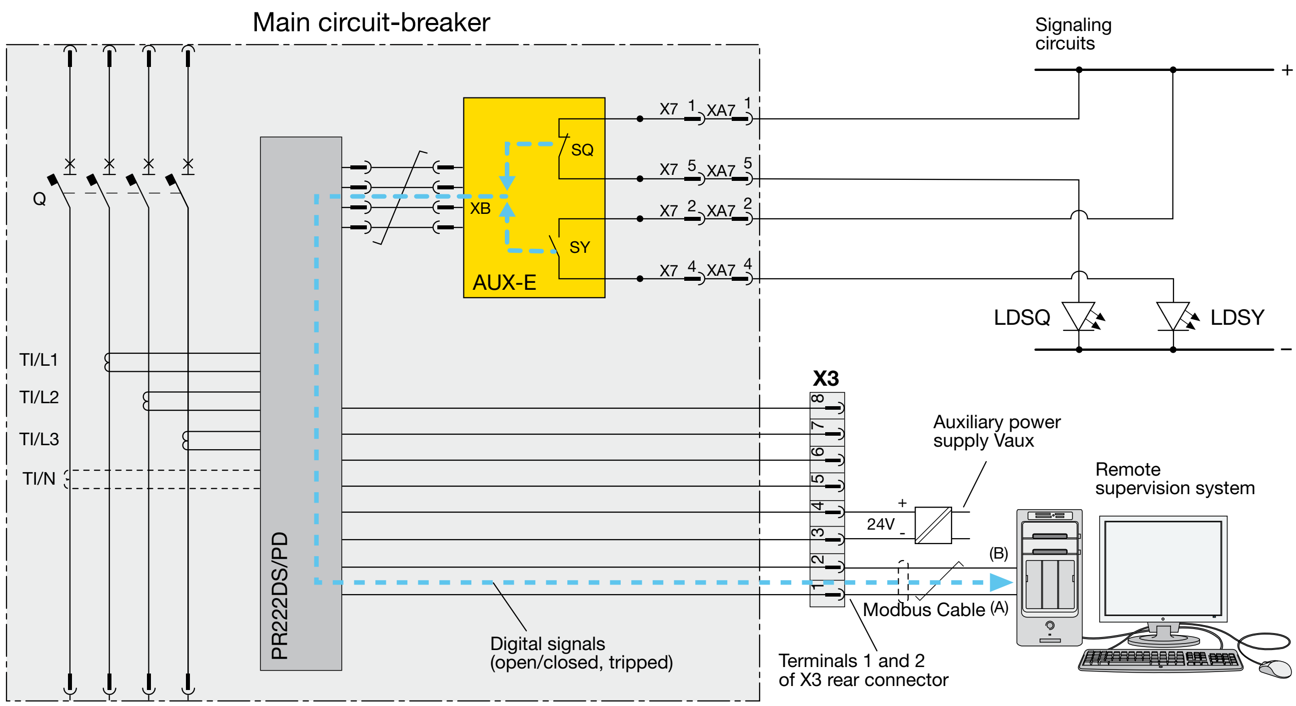
- AUX-E auxiliary contacts in electronic version for supervision only;
- motor operator with electronic interface type MOE-E for remote control too.

E.1 AUX-E auxiliary contacts in electronic version

Through the AUX-E auxiliary contacts, the microprocessor-based releases type PR222DS/PD, PR223EF and PR223DS detect the circuit-breaker state (open, closed, tripped) and make available such information for the remote supervision system, by communicating with it through the Modbus network (see Figure E.2).
The AUX-E contacts make available the information about the circuit-breaker state also on the signaling circuits of the plant through the contacts SQ and SY (see Figure E.2); in this way it is possible to obtain a redundancy of the CB state signals.

Figure E.1: Auxiliary contact module AUX-E mounted on Tmax T5

Figure E.2: Wiring diagram of AUX-E contacts connected to PR222DS/PD



Note:
SQ: Contact for the electrical signaling of circuit-breaker open/closed
SY: Contact for the electrical signaling of circuit-breaker open (tripped position)

Electrical characteristics of SQ and SY contacts:
Rated voltage: 24…350 V
Rated current: 0…100 mAmps
Max voltage: 400 V
Max continuous current: 120 mAmps
Max current (for 100 msecs): 300 mAmps

E.2 Stored energy motor operator MOE-E

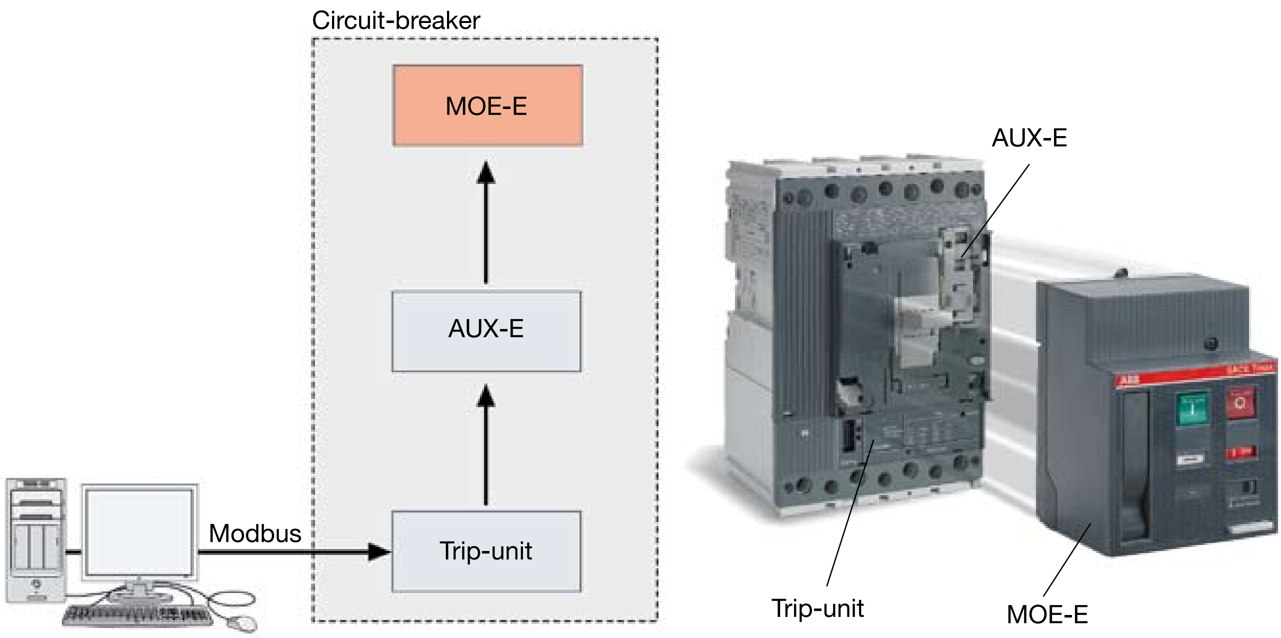
Tmax moulded-case circuit-breakers series T4, T5 and T6 can carry out opening and closing commands from remote control when they are equipped with MOE-E motor operator and AUX-E auxiliary contacts in electronic version (provided by default together with MOE-E). MOE-E motor operator is constituted, besides the real motor operating mechanism, by an electronic actuation unit, which converts the digital signals coming from the remote supervision system into their equivalent power signals necessary to perform the mechanical opening and closing operations of the circuit-breaker. The digital signals coming from the supervision system are acquired by the trip unit and sent to the motor operator according to the scheme of Figure E.3.
AUX-E auxiliary contacts communicate to the trip unit the circuit-breaker state (open/closed/tripped) and according to this information, the trip unit shall carry out or not the opening, closing and reset commands it receives by the supervision system.
In this way, the trip unit consents only to the actuation of the commands which are compatible with the real state of the circuit-breaker (for instance it shall not consent to a closing command when the circuit-breaker is in the “tripped” state).

Electrical characteristics of MOE-E:

	Tmax T4-T5		Tmax T6	
Nominal voltage Un	AC	DC	AC	DC
	-	24 [V]	-	24 [V]
	-	48÷60 [V]	-	48÷60 [V]
	110÷125 [V]	110÷125 [V]	110÷125 [V]	110÷125 [V]
	220÷250 [V]	220÷250 [V]	220÷250 [V]	220÷250 [V]
	380 [V]	-	380 [V]	-
Operating voltage	Umin = 85%Un		Umin = 85%Un	
	Umax = 110%Un		Umax = 110%Un	
Power absorbed on inrush Ps	AC	DC	AC	DC
	≤ 300 [VA]	≤ 300 [W]	≤ 400 [VA]	≤ 400 [W]
Power absorbed during normal operation Pc	AC	DC	AC	DC
	≤ 150 [VA]	≤ 150 [W]	≤ 150 [VA]	≤ 150 [W]
Operating frequency	50÷60 [Hz]		50÷60 [Hz]	
Switching time	opening [(1)]: 1.5 [s]		opening [(1)]: 3 [s]	
	closing: < 0.1 [s]		closing: < 0.1 [s]	
	reset: 3 [s]		reset: 5 [s]	
Mechanical life	20000 operations		10000 operations	
Minimum duration of electrical command	≥ 150 [ms]		≥ 150 [ms]	

[(1)] Total time, from transmission of impulse to circuit-breaker opening.

Figure E.3: Operating principle of MOE-E and AUX-E modules



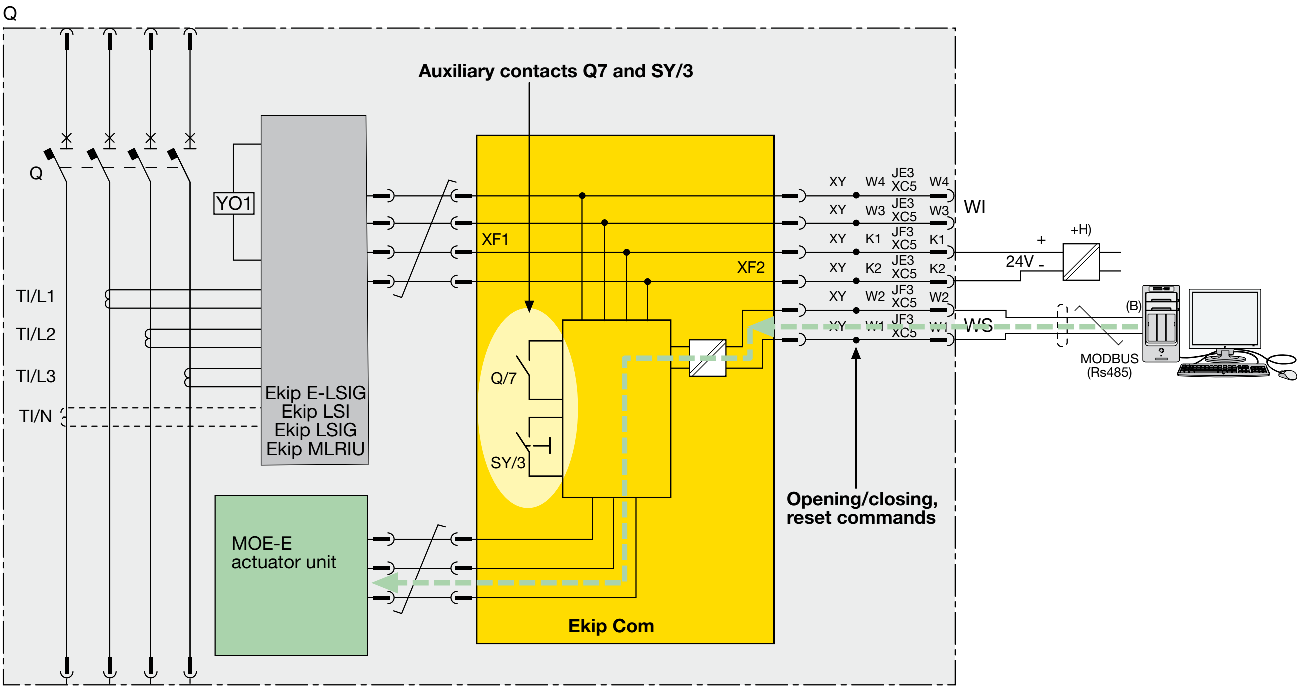
Annex F: MOE-E motor operator for SACE Tmax XT2-XT4

The moulded-case circuit-breakers type SACE Tmax XT2 and XT4 can be controlled by a remote supervision system when equipped with MOE-E stored energy motor operators.

The digital signals (opening and closing commands) are sent from the remote system to the Ekip Com module, which transmits them to the electronic actuator unit of the MOE-E. This unit converts the digital signals into the power signals necessary for operating the motor operator (to open and close the circuit-breaker).

The auxiliary contacts Q/7 and SY/3 inform the Ekip Com module about the state (open/closed, tripped) of the circuit-breaker; thus, Ekip Com will allow the commands coming from the remote system to be carried out only if they are compatible with the actual state of the circuit-breaker (for example, a closing command will not be permitted if the circuit-breaker is tripped).

Figure F.1: Wiring diagram with MOE-E



YO1: opening solenoid of the microprocessor-based overcurrent release.

Electrical characteristics of MOE-E: (for SACE Tmax XT2 and XT4)

Nominal voltage Un	AC	DC
	-	24 [V]
	-	48÷60 [V]
	110÷125 [V]	110÷125 [V]
	220÷250 [V]	220÷250 [V]
	380÷440 [V]	-
	480÷525 [V]	-
Operating voltage	Umin = 85%Un	
	Umax = 110%Un	
Power absorbed on inrush Ps	AC	DC
	≤ 300 [VA]	≤ 300 [W]
Power absorbed during normal operation Pc	AC	DC
	≤ 150 [VA]	≤ 150 [W]
Operating frequency	50÷60 [Hz]	
Switching time	opening [(1)] < 1.5 [s]	
	closing < 0.1 [s]	
	reset < 3 [s]	
Mechanical life	25000 operations	
Minimum duration of electrical opening and closing command	≥ 150 [ms]	

(1) Total time, from transmission of impulse to circuit-breaker opening.

Annex G: The parity bit

The parity bit is an additional control bit in queue after each transmitted character to avoid communication errors.
With the parity control in even mode, this bit is set to:

- 1 if in the character to be sent there is an odd number of 1s (ones)
- 0 if in the character to be sent there is an even number of 1s (ones)

so that there is always an even number of 1s (ones) in the character to be transmitted.

In compliance with this rule, the receiver shall count the number of bits set to 1 and if the counted number is odd, it shall understand that there must have been some problem and shall ask to the transmitter to send the character again.
Vice versa, when the parity control is in odd mode, the parity bit shall be set to 1 or to 0, so that there is always an odd number of ones in the character to be transmitted.

Even parity		
Character to be transmitted	Parity bit	Transmitted character
00111000	**1**	**001110001**

Odd parity		
Character to be transmitted	Parity bit	Transmitted character
00111000	**0**	**001110000**

Two communicating devices, to understand each other, must be set to the same control mode of the parity bit.

Technical Application Papers

QT1
Low voltage selectivity with ABB circuit-breakers

QT2
MV/LV trasformer substations: theory and examples of short-circuit calculation

QT3
Distribution systems and protection against indirect contact and earth fault

QT4
ABB circuit-breakers inside LV switchboards

QT5
ABB circuit-breakers for direct current applications

QT6
Arc-proof low voltage switchgear and controlgear assemblies

QT7
Three-phase asynchronous motors
Generalities and ABB proposals for the coordination of protective devices

QT8
Power factor correction and harmonic filtering in electrical plants

QT9
Bus communication with ABB circuit-breakers

QT10
Photovoltaic plants

QT11
Guidelines to the construction of a low-voltage assembly complying with the Standards IEC 61439 Part 1 and Part 2

QT12
Generalities on naval systems and installations on board

QT13
Wind power plants

Contact us

ABB SACE
A division of ABB S.p.A.
L.V. Breakers
Via Baioni, 35
24123 Bergamo - Italy
Phone: +39 035 395 111
Fax: +39 035 395 306-433
www.abb.com

1SDC007108G0202 - 02/2012 - 3.000