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Bus communication with ABB circuit-breakers

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Index

1 Introduction

Due to the ever growing use of the automation and supervision systems for industrial processes for a better management of the electrical and technological plants the 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 the 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 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 four main parts:

- introduction to digital communication and basic concepts regarding communication protocols;
- supervision of electrical distribution plants;
- ABB solution for bus communication;
- some application examples regarding ABB SACE circuit-breakers used for the automated management of electrical distribution plants.

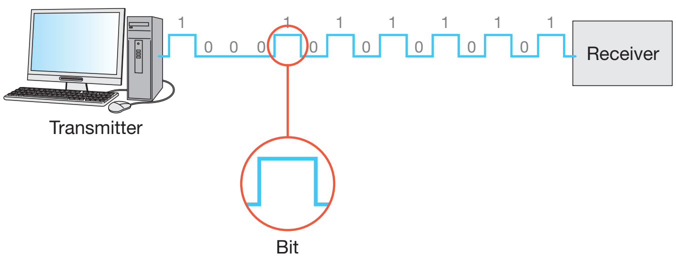
In addition there are also some annexes giving a deep insight into the functional and applicative aspects of the products (communication modules, measuring modules, auxiliary contacts in electronic version and suitable connectors) necessary for the measuring and bus communication functions of automatic circuit-breakers.

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, that is 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:

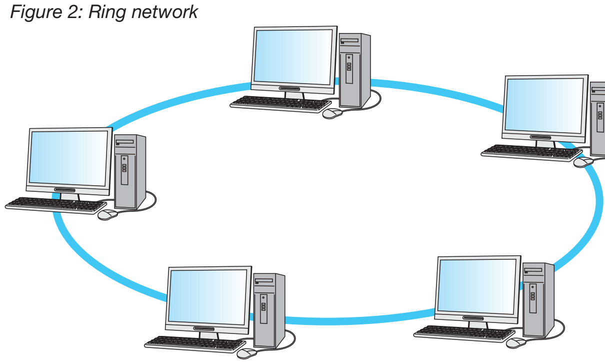
- the node (an "intelligent" device capable of dialogue with other devices) is the point of data transmission and/or reception;

- 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:

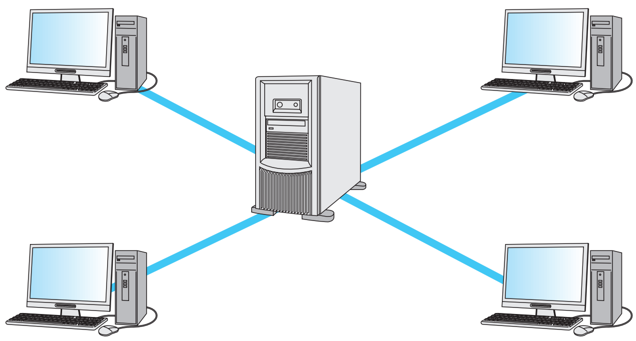
- Ring network
Ring networks are constituted by a series of nodes (in Figure 2 these are represented by personal computers) interconnected to get a closed ring.

Figure 2: Ring network



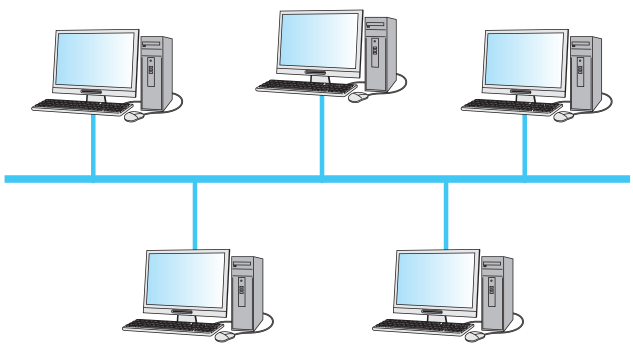
- Star network
Star networks are based on a central node to which all the other peripheral nodes are connected.

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.

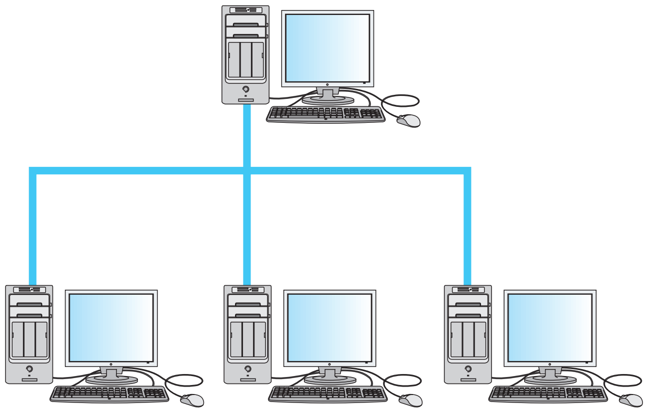
Figure 4: Bus network



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

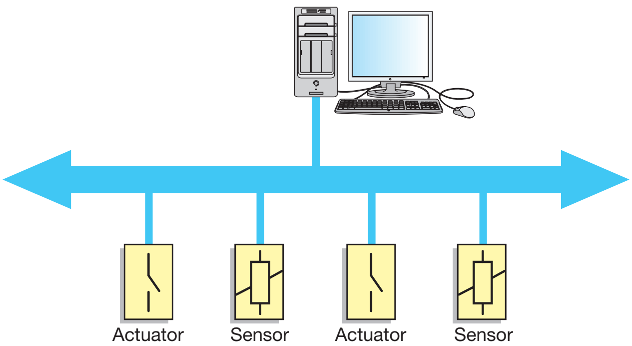
1) data interchange between the personal computers, in a company or a firm, linked through a LAN network[2].

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 between them; 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 let the different devices in industrial applications communicate are very numerous and vary according to the communication requirements of each application, and 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 relevant peripherals.

In the following chapters these protocols are not taken into consideration: the discussion shall be limited to a description of the protocols dedicated to the industrial communication between the field devices, that is those devices which interact directly 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 entity, 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

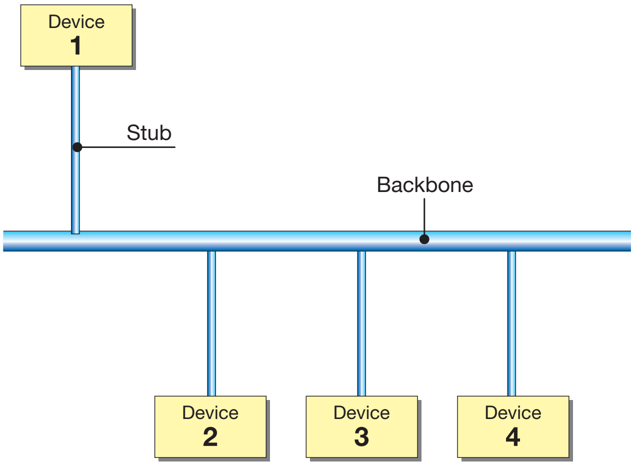
When taking into consideration the physical layer it is possible to distinguish between:
- wireless systems, which use as physical medium radio waves, infrared rays or luminous signals which are propagated in free space;

- 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 mostly used physical layer interfaces 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

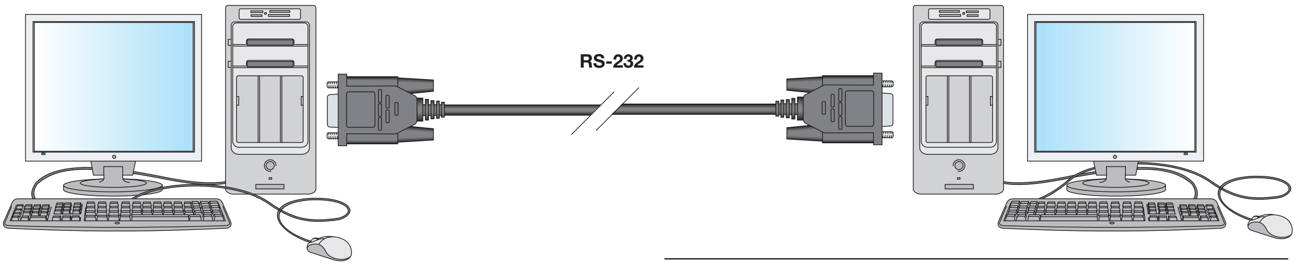
When speaking of physical layer we have:
The RS-232 interface, which is so common in personal computers to be known as "serial port", is an asynchronous point-to-point serial communication system allowing full-duplex operation.

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.

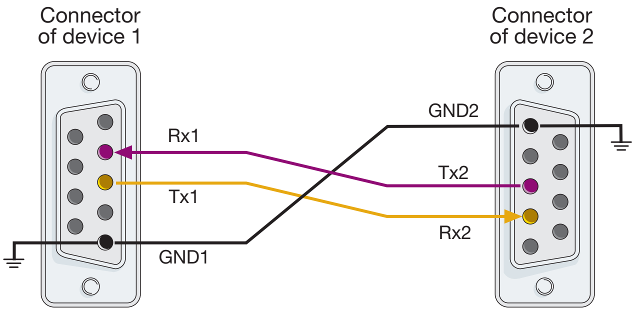
Figure 11: Point-to-point connection between two PCs



- 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);

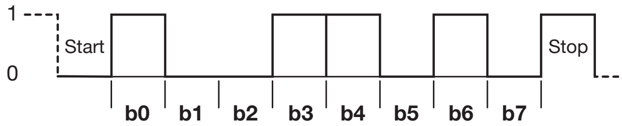
[3] *Flow control: method of controlling the flow of information.*
Handshaking: exchange of pre-established signals between two devices so that a correct communication is achieved. Thanks to this signal exchange, the devices inform that they have some data to transmit or that they are ready to receive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

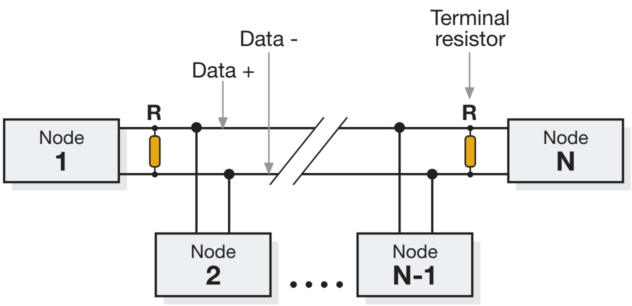
For instance, in the bit frame of Figure 13, it is possible to identify:
- 1 start bit
- 8 bits (b0….b7) constituting the character (the transmitted data)
- 1 stop bit.

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, it is spoken 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, it is spoken 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 through 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.

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]

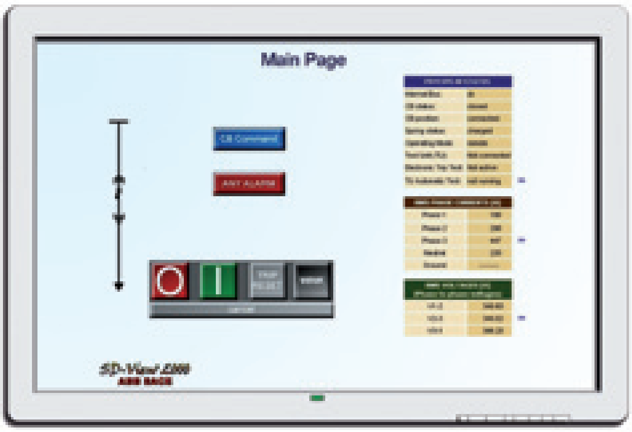
When the master unit (e.g. a PC) wants to read the current values, it sends to the circuit-breaker a message containing:

- 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 understand 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.
Figure15 shows the user interface of the software SD-View2000, through which an operator can:

- view the current values and the data contained in the circuit-breaker protecting a section of an electrical plant;
- carry out circuit-breaker opening and closing operations from remote control.

Figure 15: Example of user interface for the supervision of an electrical installation



[6] For further information on the structure of the Modbus logical map of the ABB trip units equipped with communication interface reference shall be made to the following documents:
- Instruction manual PR122-3/P+PR120/DM-PR332-3/P+PR330/DM Modbus System Interface
- Instruction manual PR223EF Modbus System Interface
- Instruction manual PR223DS Modbus System Interface
- Instruction manual PR222DS/PD Modbus System Interface

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	Modbus	**YES COMMUNICATION** Compatibility on all the layers of the protocol
Physical layer	RS-485	RS-485	
Logical layer	Modbus	Modbus	**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	**NO COMMUNICATION** Incompatibility on the logical layer of the protocol
Physical layer	RS-485	RS-485	
Logical layer	Modbus	Modbus	**NO COMMUNICATION** Incompatibility on the physical layer of the protocol
Physical layer	RS-485	RS-232	
Logical layer	Profibus-DP	Modbus	**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

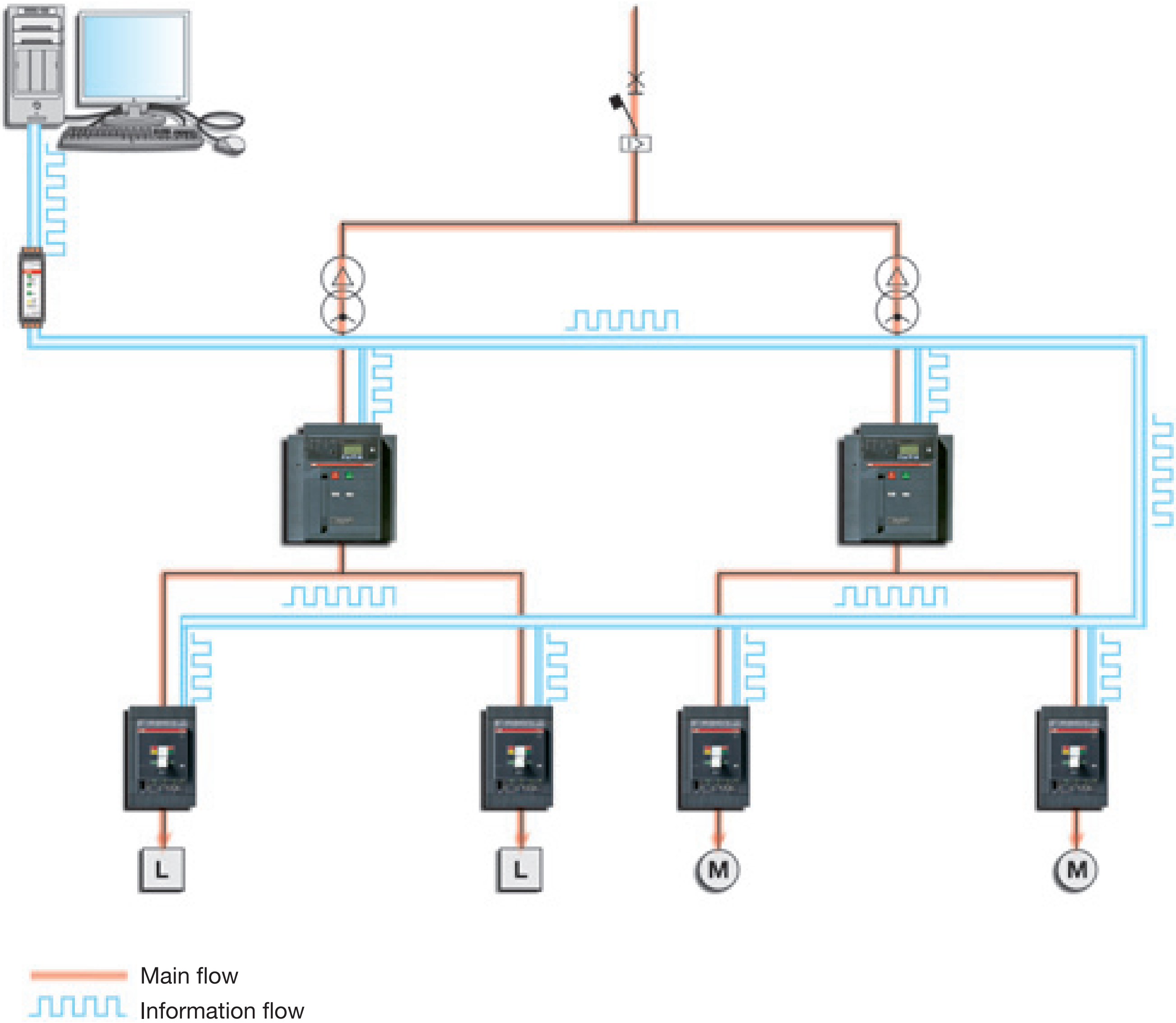
A low voltage electrical distribution plant can be considered as an industrial process oriented towards the distribution of electrical energy, and therefore, it also needs a supervision and control system to increase reliability and improve managing of the installation.

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;
- an information flow or informative flow (digital flow) constituted by all the information, the data and the commands useful for the management and control of the plant.

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

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



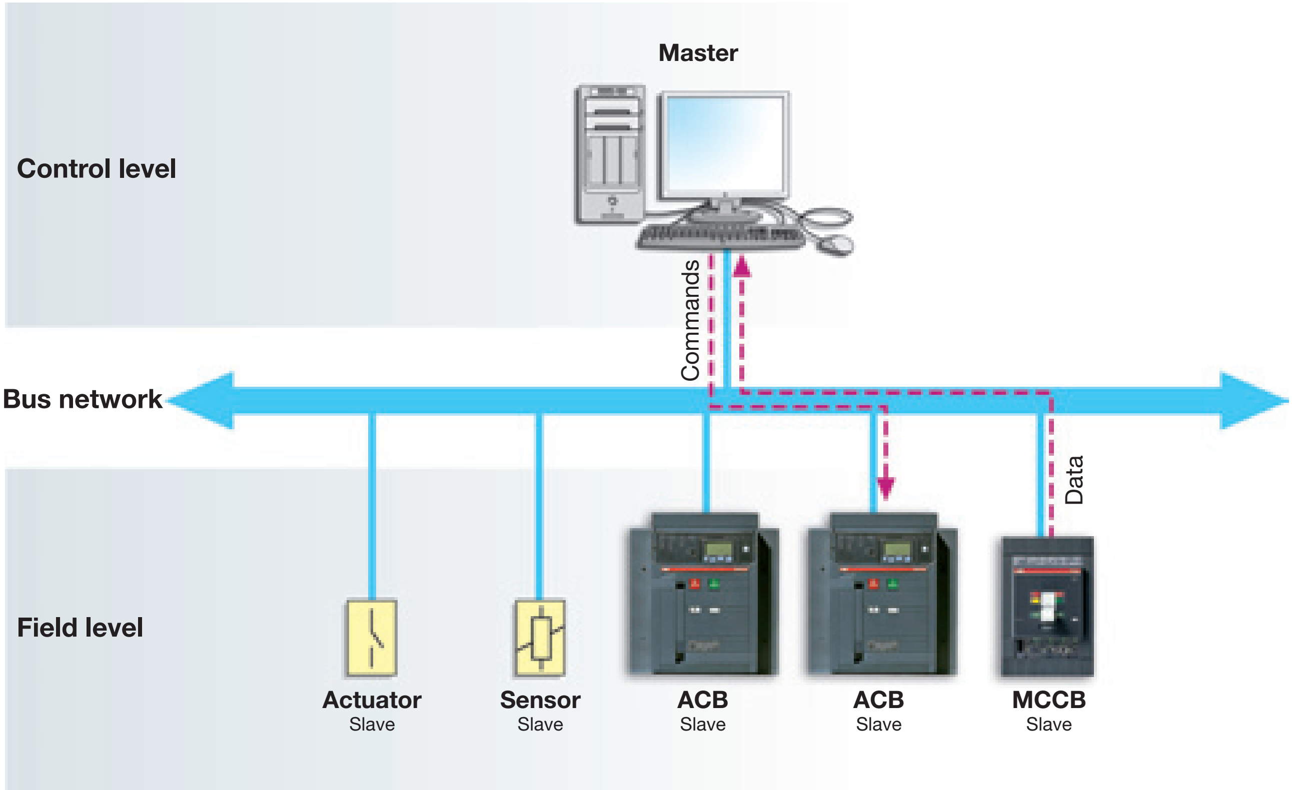
According to the extent and the complexity of the installations to be managed, it is possible to implement supervision systems with different architectures, from the simplest (two-layer architecture) to the most complex ones (multi-layer architecture).
In this document, for a simple treatment of the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

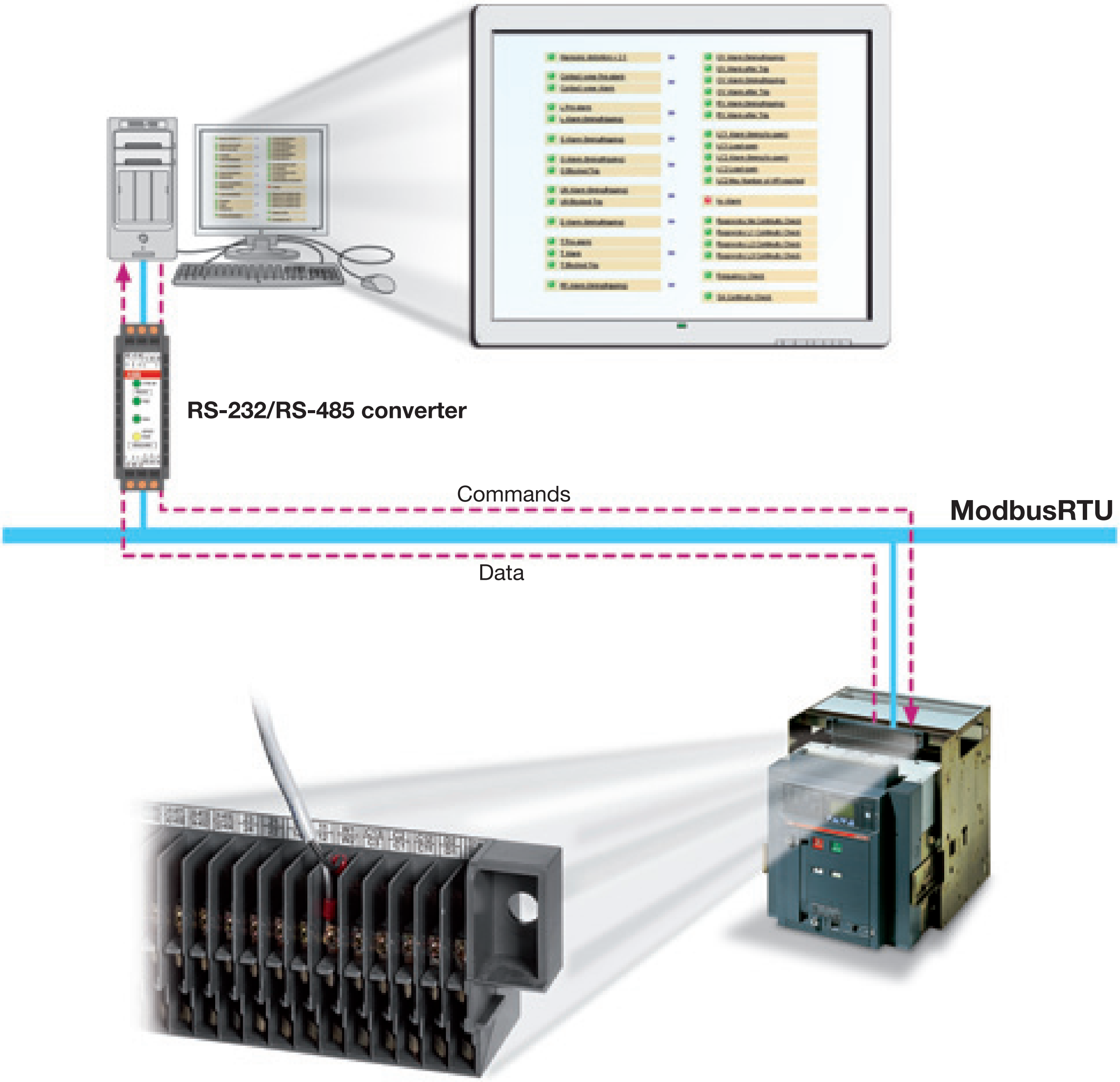
- to know the diagnostics data of the protection devices (e.g. percentage of contact wear) in order to schedule preventive maintenance compatible with the working cycle of the supplied process, so as to limit to a minimum the down times and guarantee service continuity for the installation.

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 and the products which allow ABB SACE circuit-breakers to be interfaced on Modbus networks, for the supervision and remote control of low voltage electrical distribution plants.

4.1 Air and moulded-case circuit-breakers

4.1.1 Emax air circuit-breakers E1-E2-E3-E4-E6

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).

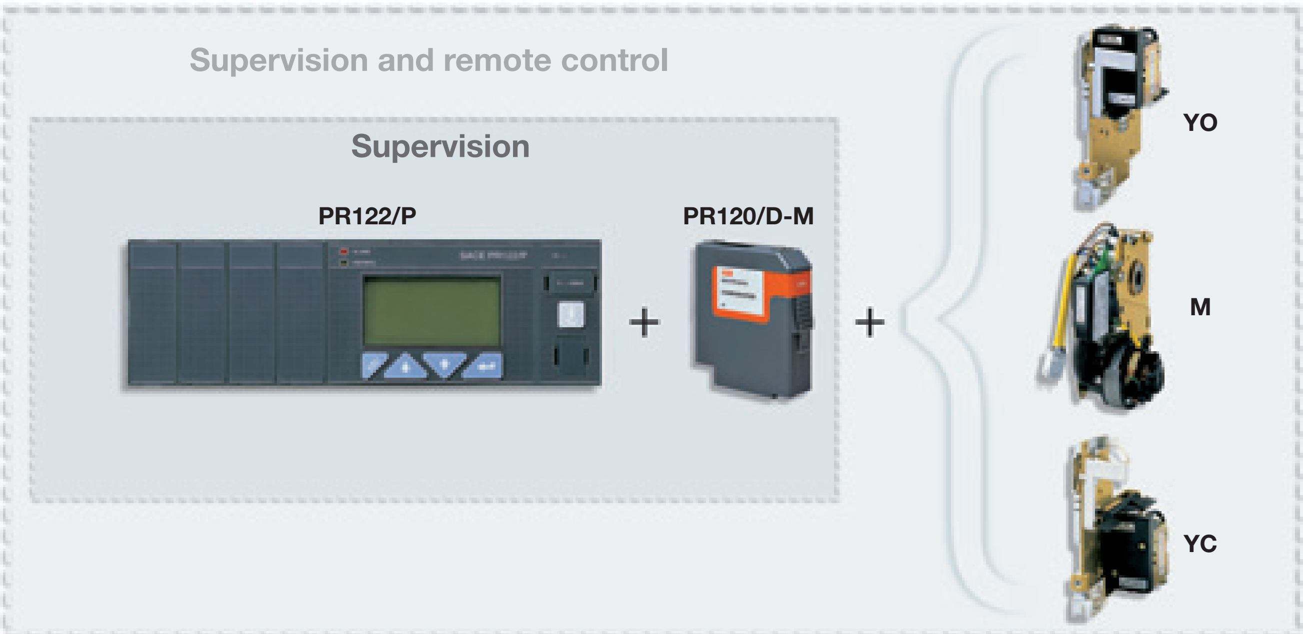
As regards bus communication, remind that the auxiliary supply voltage Vaux is necessary for the trip units PR122/P and PR123/P (for its technical characteristics see Annex B).

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.

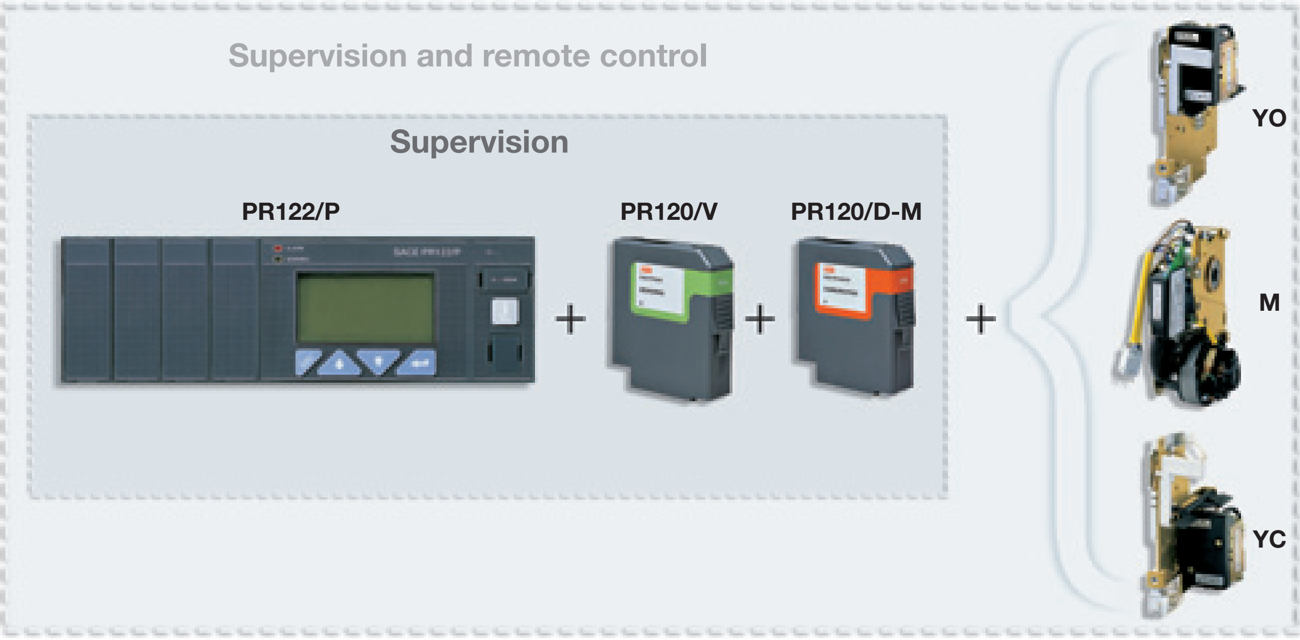
PR122/P electronic trip unit

- 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.

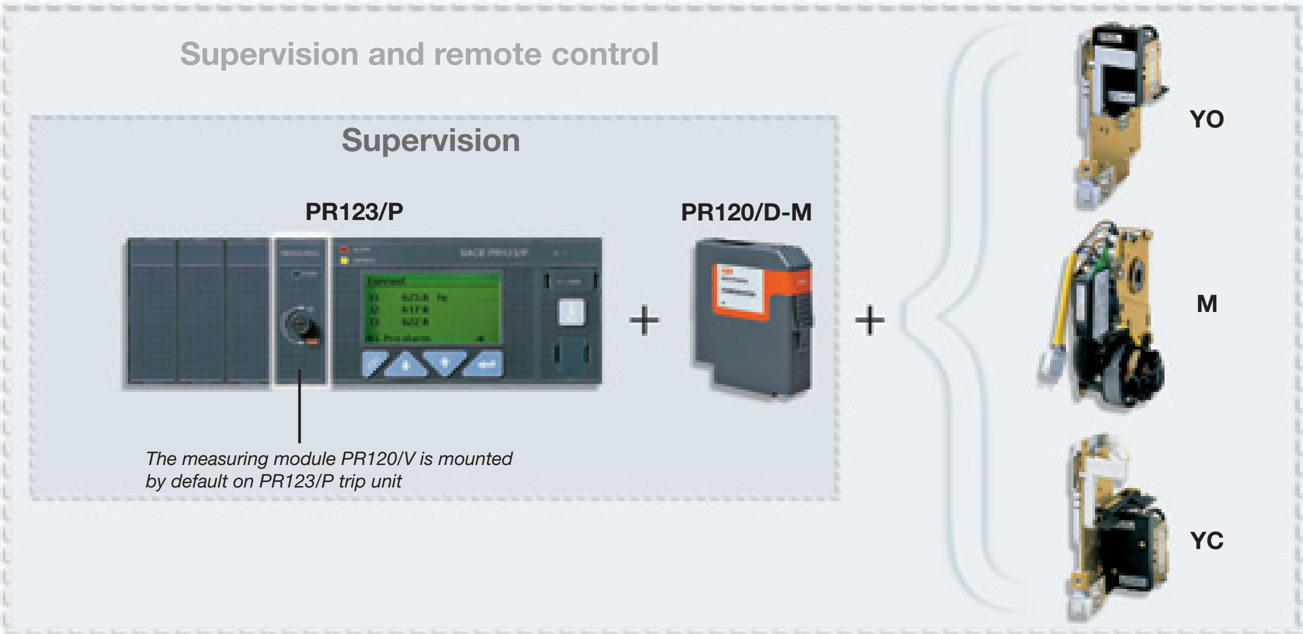
- PR122/P + PR120/D-M communication module + remote control accessories (YO, YC, M)



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

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

Modbus communication: supervision and remote control

Emax X1 air circuit-breakers provided 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 to be interfaced with Modbus networks 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. To make available for the remote supervision system the information about the circuit-breaker state (open/closed, tripped) Tmax T7 circuit-breakers must be equipped with the auxiliary contacts AUX;

- 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).

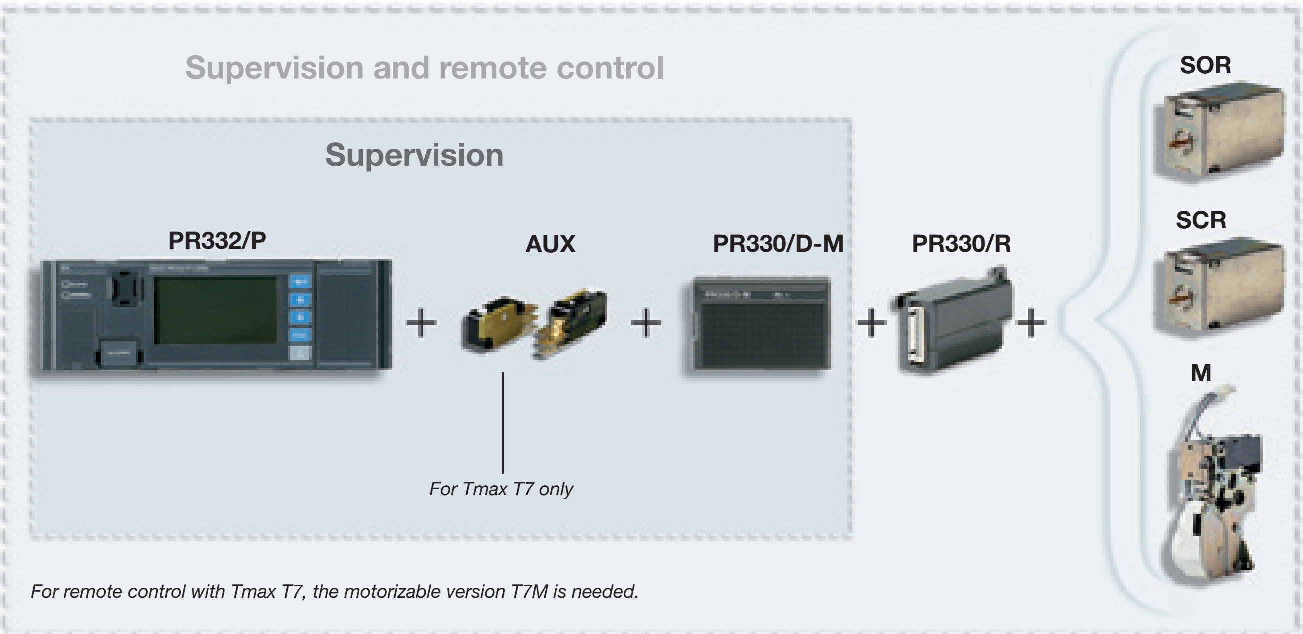
The measured values can be sent, by means of PR330/D-M, to the remote supervision system.

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.

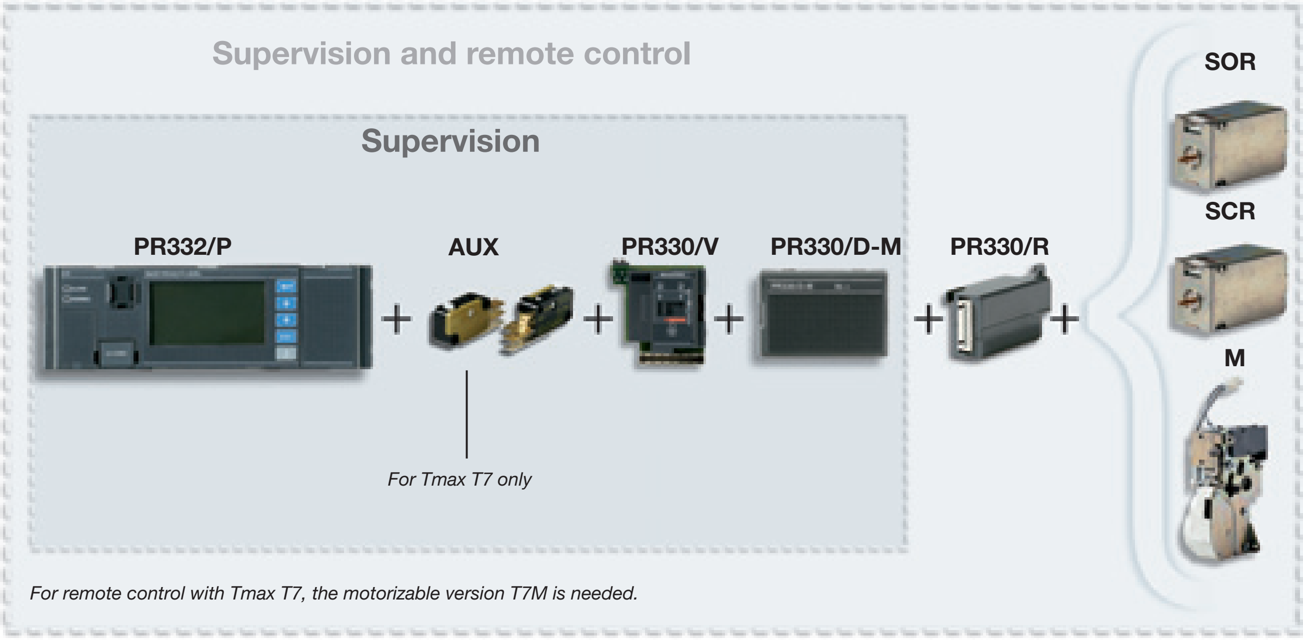
PR332/P electronic trip unit for Emax X1 and Tmax T7

- 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.

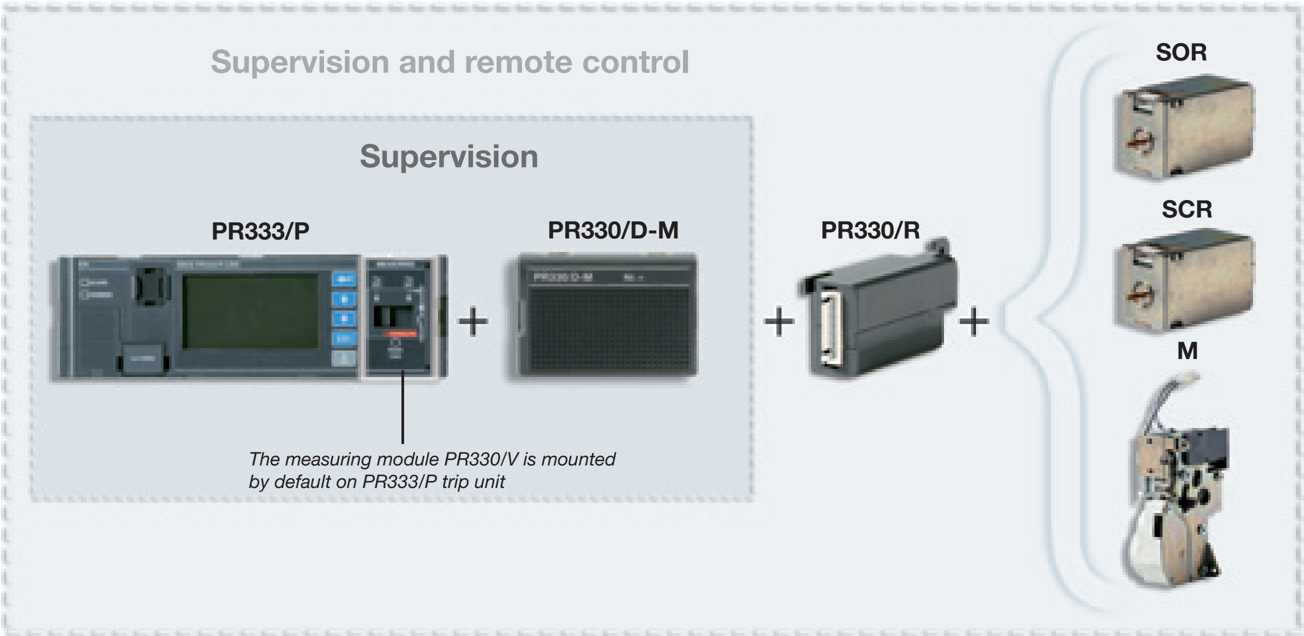
- PR332/P + PR330/D-M communication module + PR330/V measuring module + accessories for the remote control (PR330/R, SOR, SCR, M).



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.

4.1.3 Tmax moulded-case circuit-breakers 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).

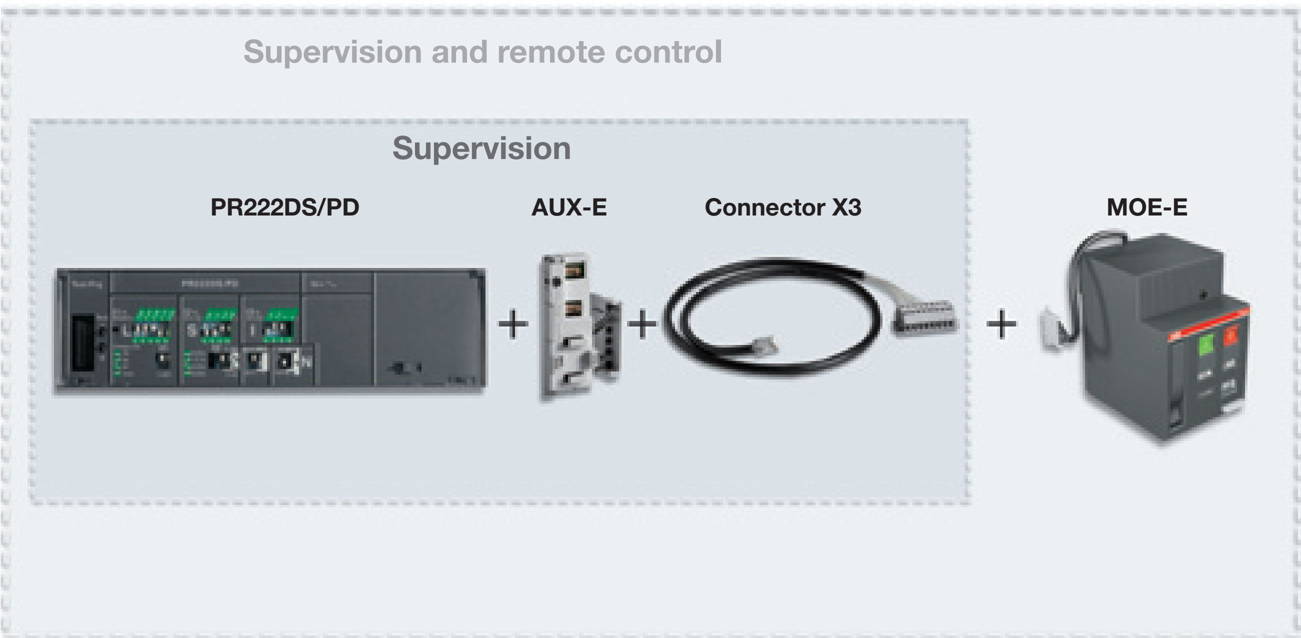
As regards bus communication, remind that the auxiliary supply voltage Vaux is necessary for the trip units PR222DS/PD, PR223EF and PR223DS (for its characteristics see Annex B).

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.

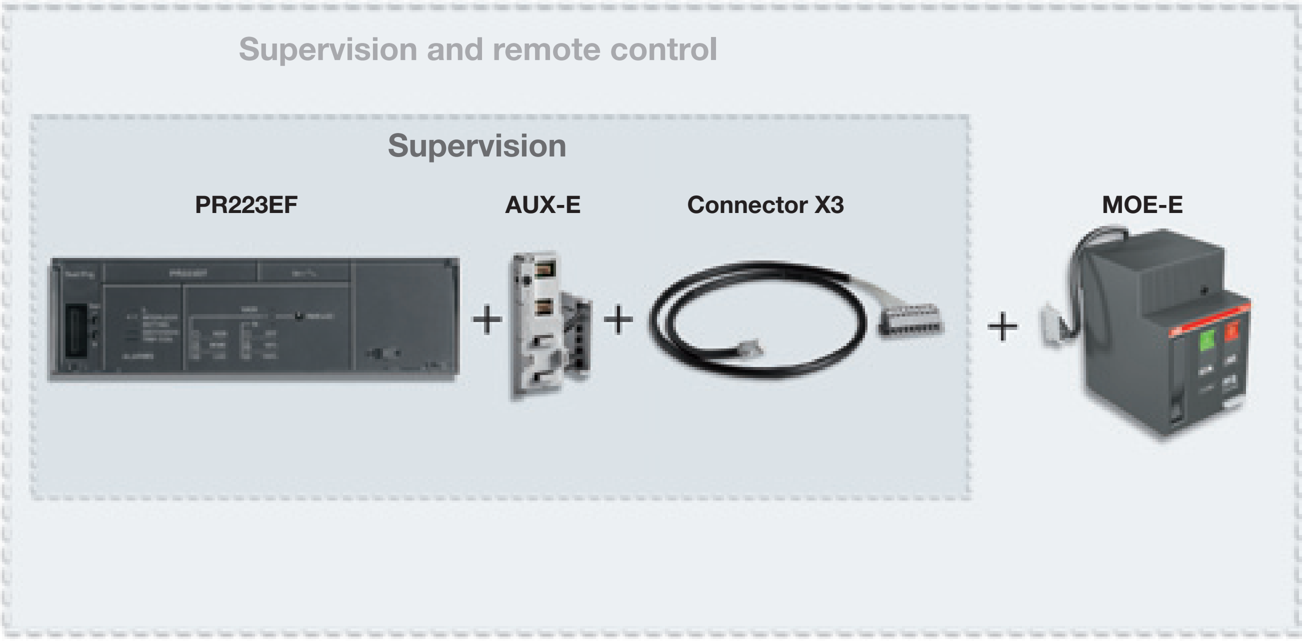
PR222DS/PD electronic trip unit

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

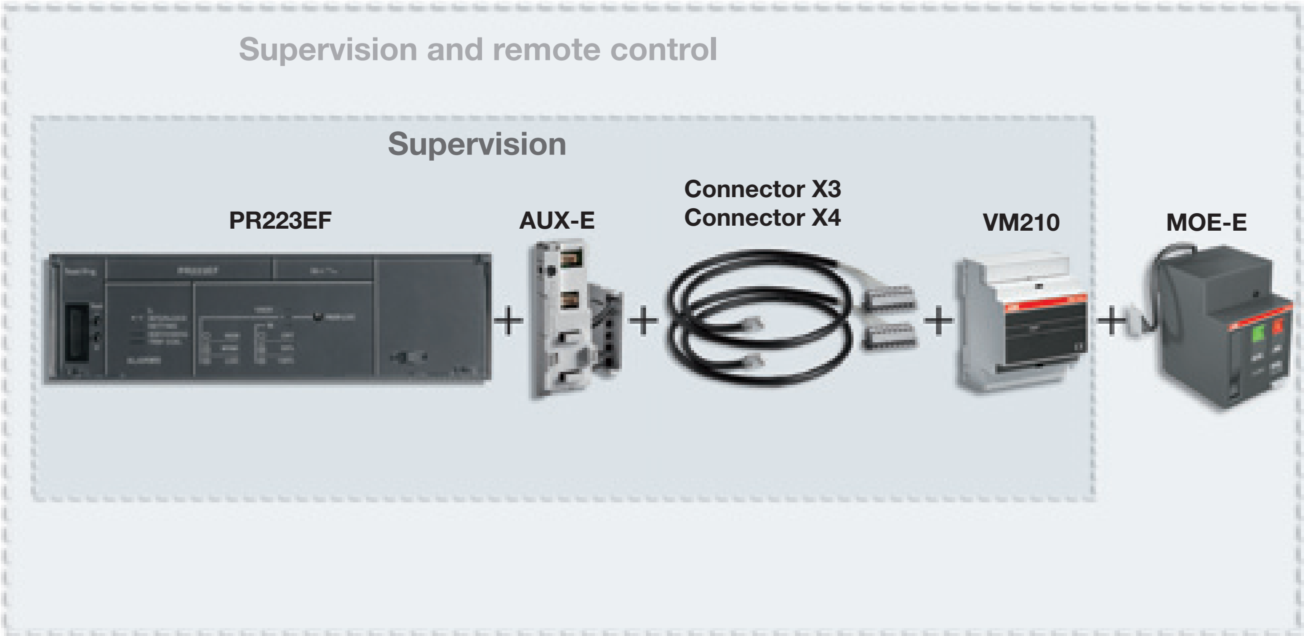


PR223EF electronic trip unit

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

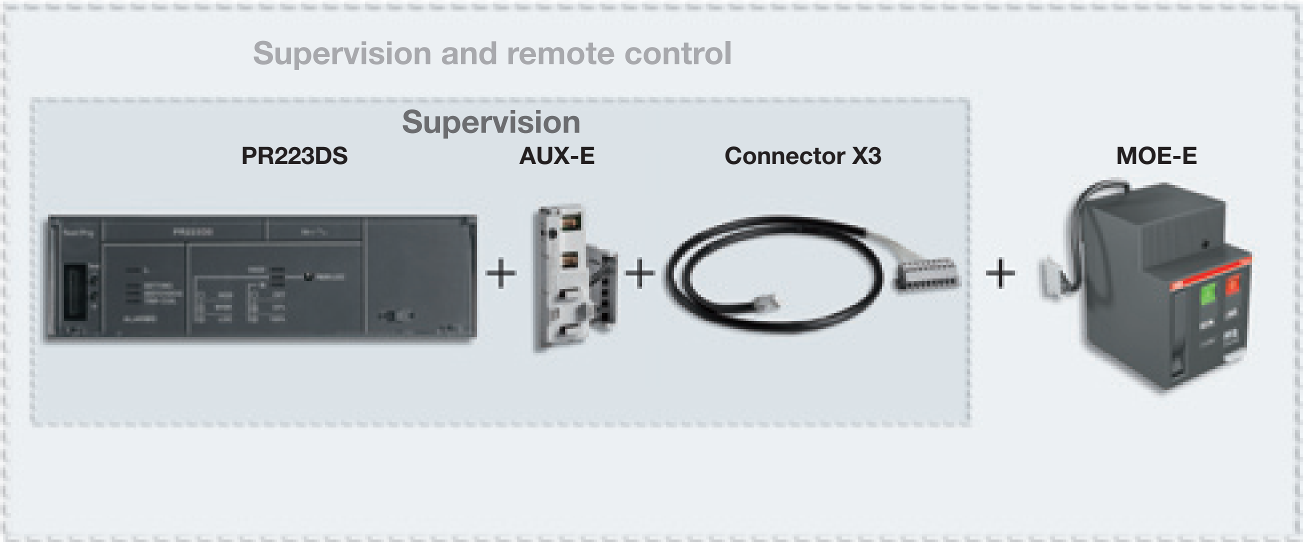


- PR223DS + AUX-E auxiliary contacts in electronic version + X3 connector + X4 connector + VM210 measuring module + MOE-E motor operator with electronic interface

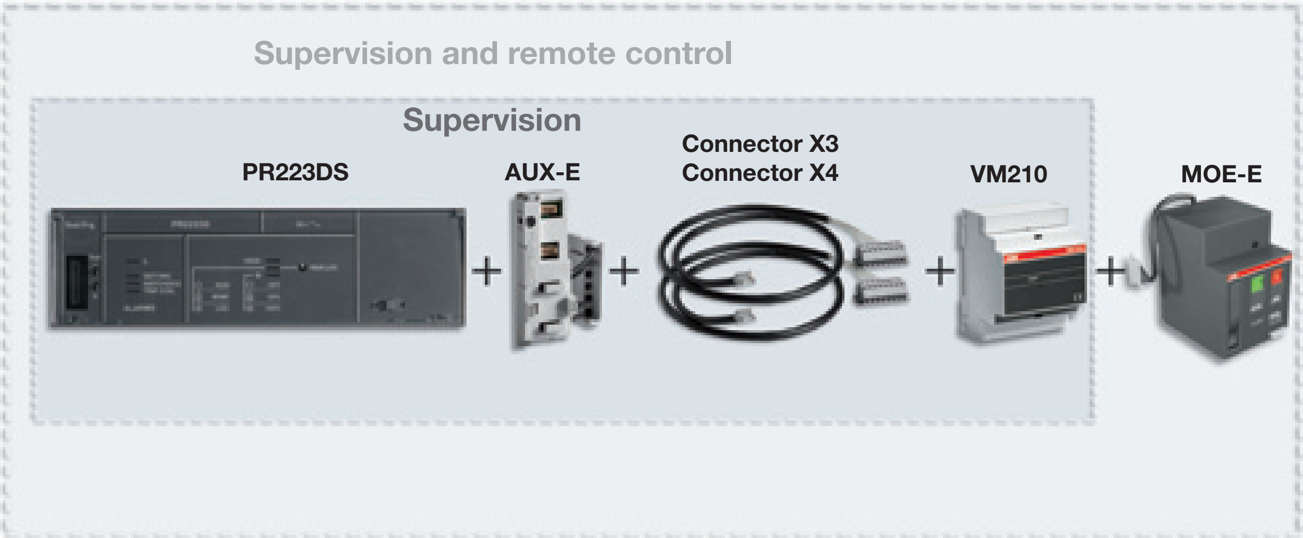


PR223DS electronic trip unit

- *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 on the dialogue functionalities and on the characteristics of the products described in this chapter please refer to the relevant product technical catalogues and manuals.

4.2 SD030DX solution for the circuit-breakers without Modbus 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

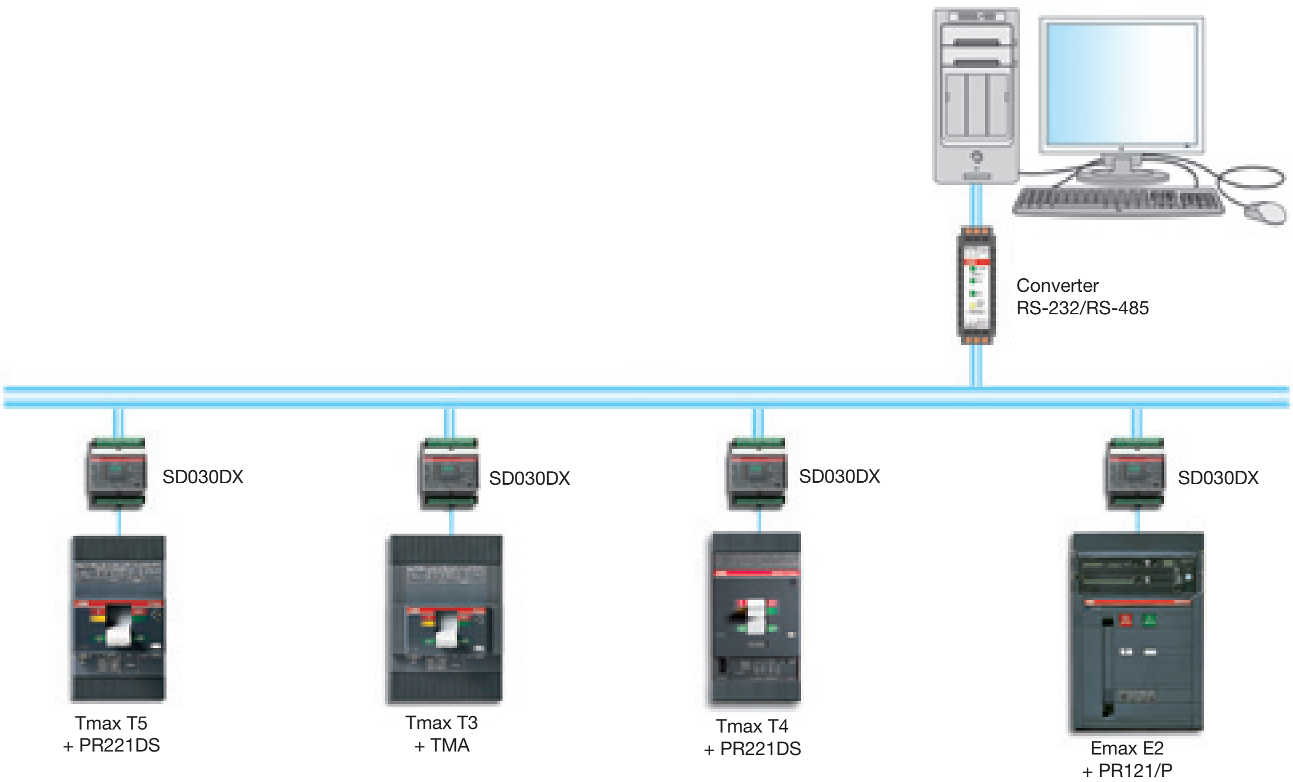
to a Modbus network.
The circuit-breakers and the switch-disconnectors connected in this way appear on the Modbus network as slave units and can communicate with whatever master (PC, PLC, SCADA).
This makes it possible for the supervision systems to manage also these apparatus.
In particular, the supervision 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.

Figure19: SD030DX flex interface

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



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 status (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-discon-nector 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 status (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

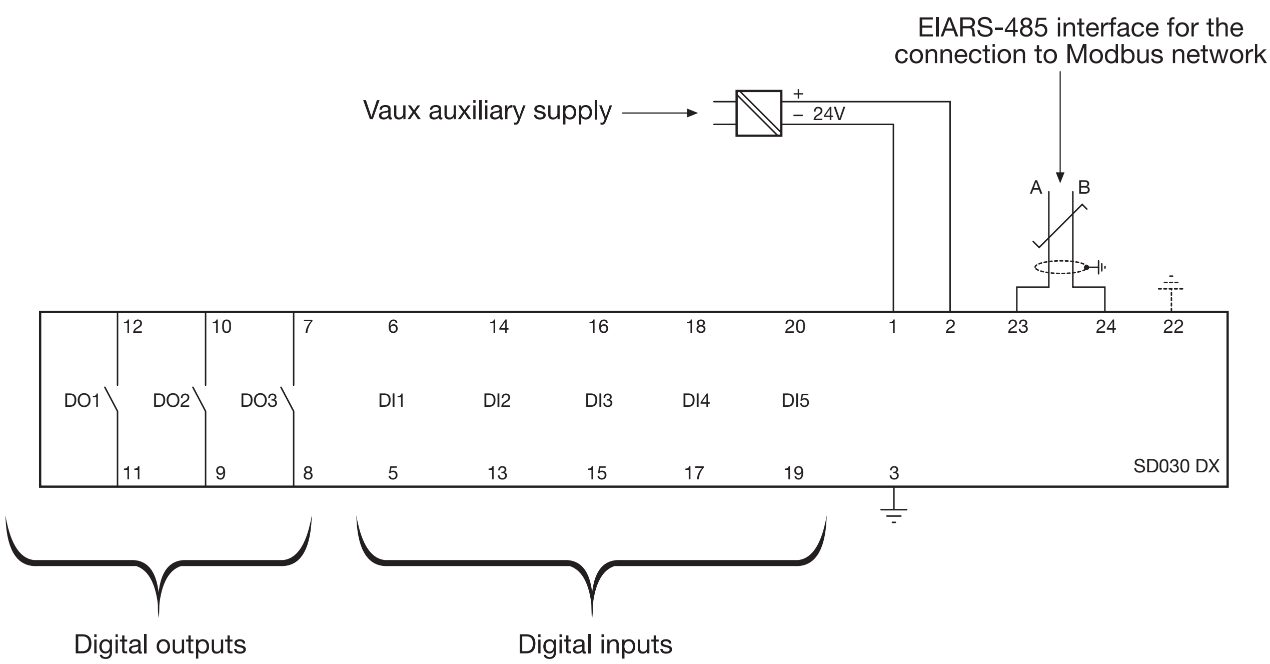
The SD030DX units carry out the commands (opening, closing and reset) sent by the supervision system to the circuit-breaker/switch-disconnector.

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 YR: reset coil M: geared motor for the automatic charging of the closing springs	Opening Closing Reset
E1/MS ÷ E6/MS	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

Figure 20: Circuit diagram of SD030DX



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

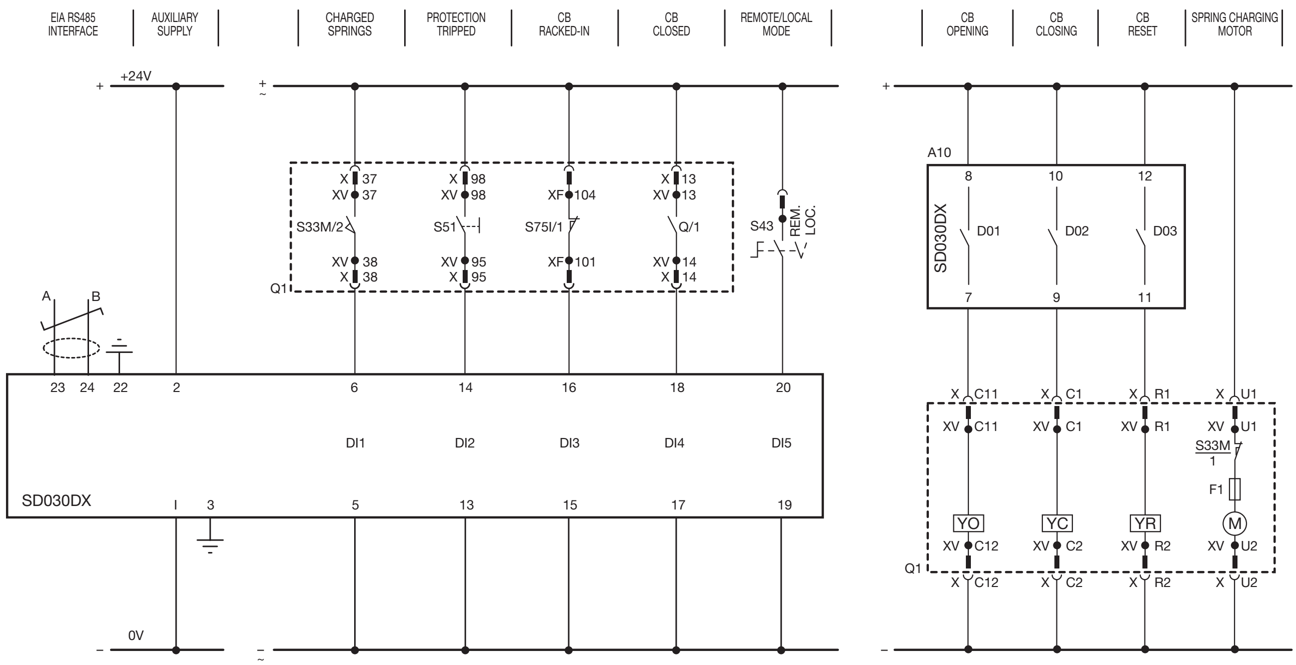
- the auxiliary circuits of the circuit-breaker through DI inputs and DO outputs, so that the unit can interact with the CB and make it possible command actuation (opening, closing, reset) and the detection of CB state;
- the Modbus network, through EIA RS-485 serial interface, to communicate with the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



4.3 Modbus network RS-485 (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.

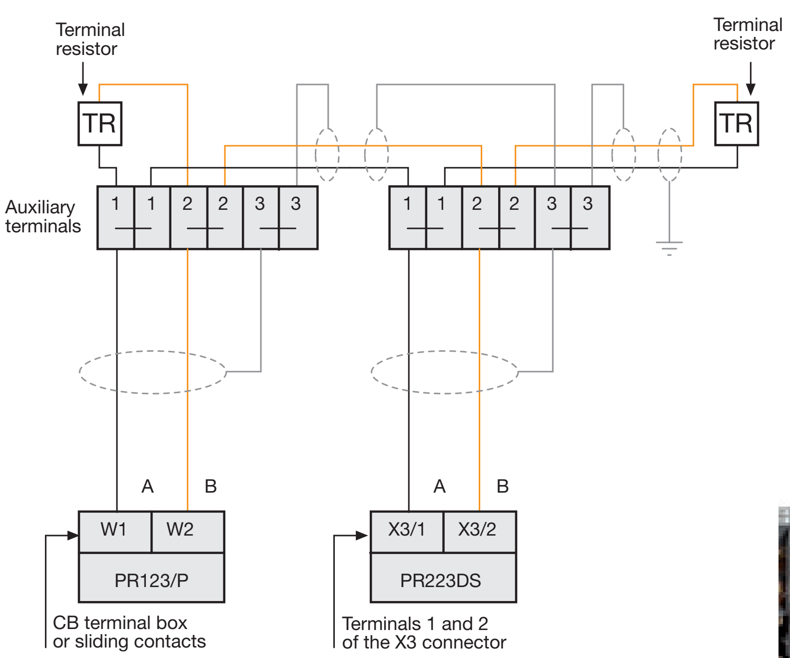
1. Connection port
Each device is equipped with a communication port with two terminals, conventionally called A and B.
The communication cable is connected into these two terminals, so that all the devices involved by the communication are connected in parallel.
All the terminals A and B shall be connected 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.

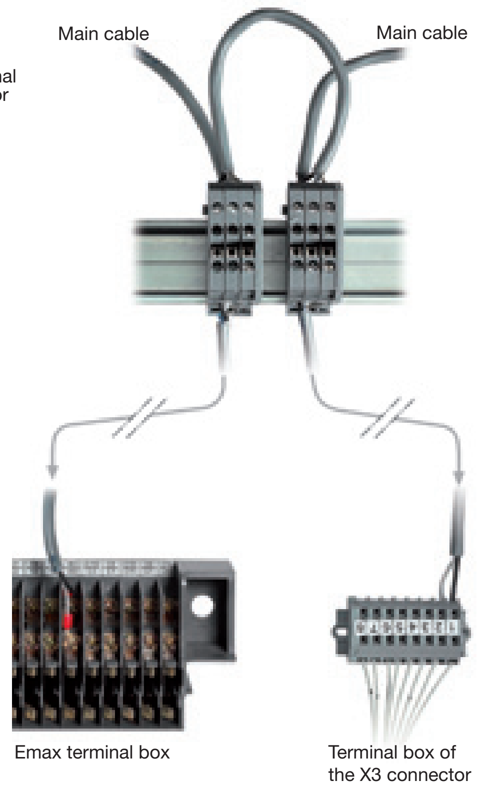
In ABB SACE circuit-breakers, the communication terminals are represented as shown in the following table:

Circuit-breaker	Trip uit	Terminal A	Terminal B	Note
Emax	PR122/P and PR123/P	W1	W2	CB delivery terminal box or sliding contacts
Emax X1 Tmax T7/T7M	PR332/P and 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

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

Figure 22: Electrical wiring diagram of an Emax and a Tmax to the Modbus network





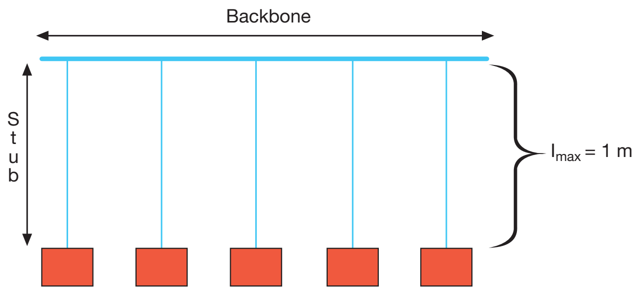
In order to avoid errors when many devices are connected, it is advisable to use the same color for all the wires connected respectively to the terminals A and B of the different devices (e.g. white for A and blue for B); this makes easier the identification of reversed wiring.
Also on the Master device, 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.

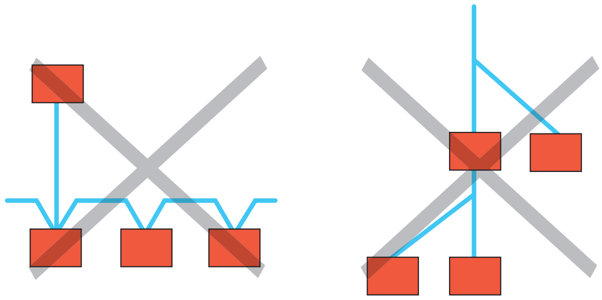
The presence of longer stubs could cause reflections of the signals with the possible induction of disturbances and consequent errors in the data reception.
Figure 23 shows the example of a correct bus connection.

Figure 23: 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

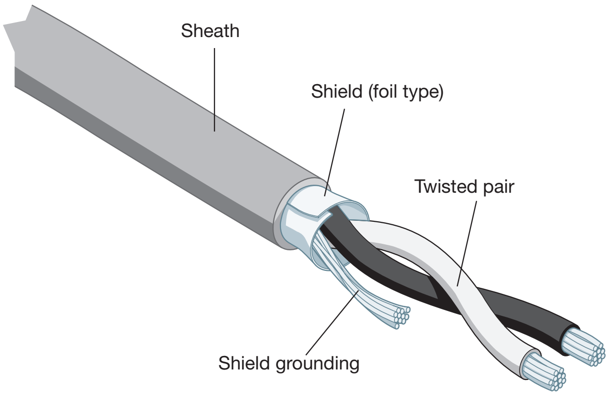
The cable to be used is a shielded twisted pair cable (type for telephone).

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.

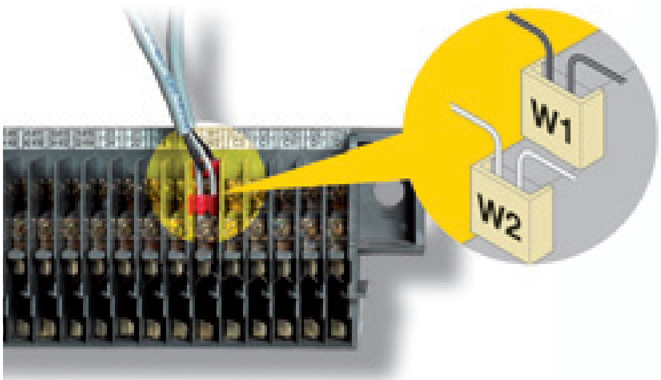
Figure 25: Detail of a shielded twisted pair cable



6. Connection to the terminals

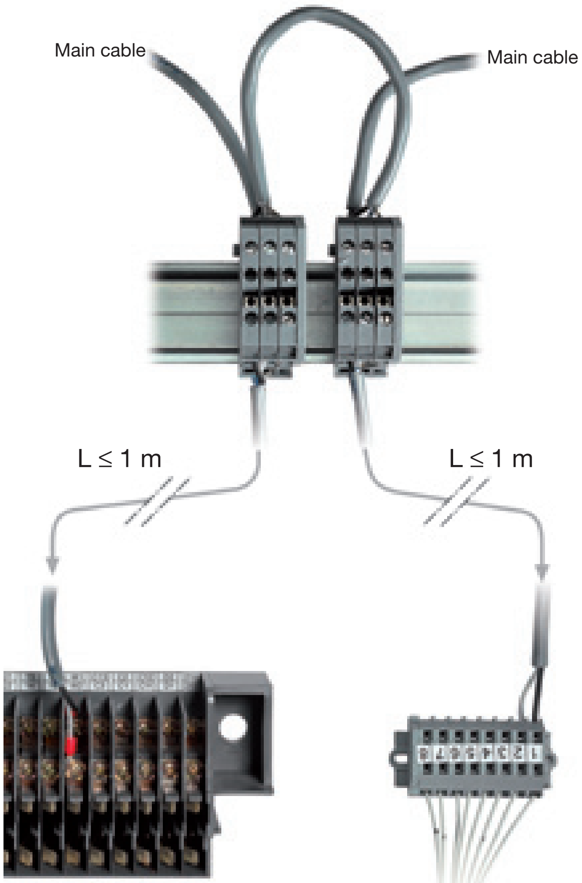
In some countries it is allowed to insert two cables into the same screw terminal. In such case, it is possible to connect the main cable directly to the terminals of the circuit-breaker, without a stub as shown in Figure 26.

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.

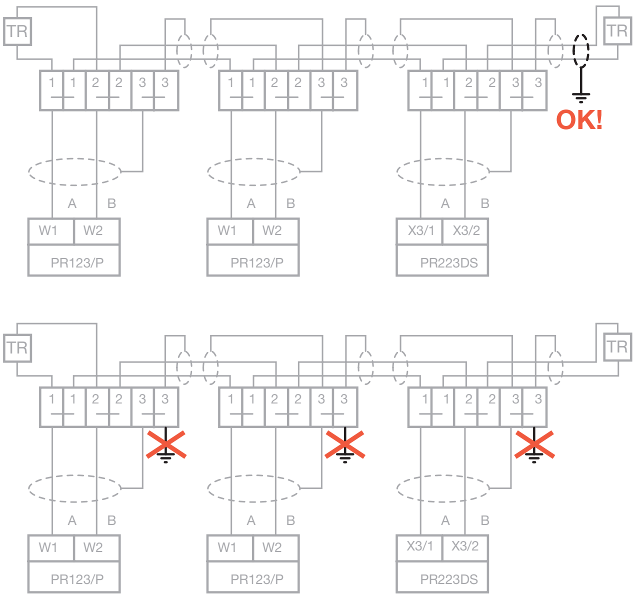
Figure 27: Connection to the circuit-breaker through auxiliary terminals



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.

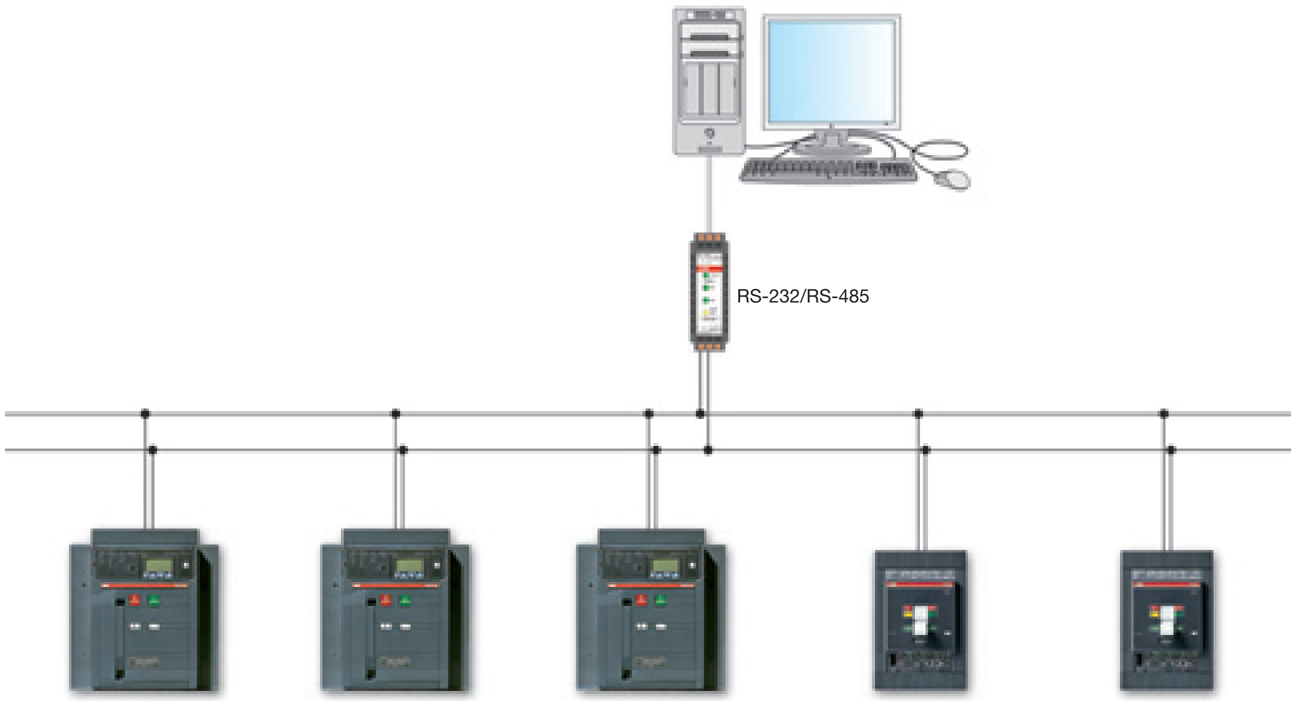
An internal terminating resistance is not provided for ABB SACE devices type new Emax, Emax X1 air circuit-breakers and Tmax moulded-case circuit-breakers.
If other devices are connected in addition to ABB SACE circuit-breakers, it is necessary to verify whether they are equipped or not with terminating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



4.3.1 Modbus 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.

[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.*

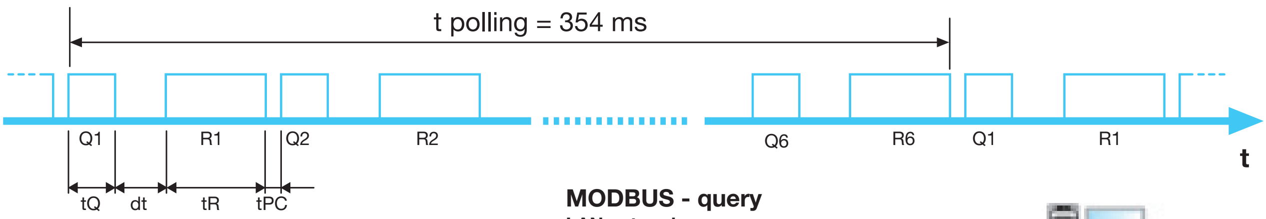
The circuit-breakers are queried by the PC with cyclic polling, that is cyclically one after the other, so that the complete scanning of the plant is carried out within a predictable time (polling time).

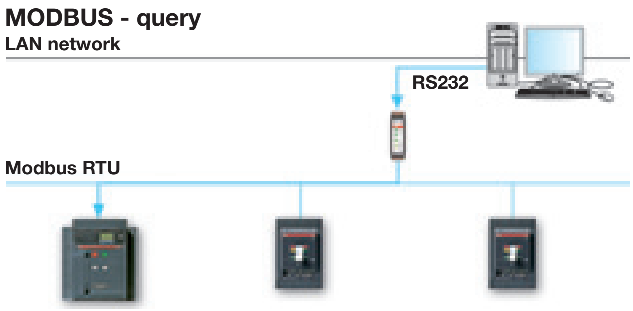
For instance, supposing we want to read the current values from 6 Tmax circuit-breakers equipped with the electronic trip unit PR222DS/PD.
For the communication sequence between each circuit-breaker and the PC, the following times are assumed:

- 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.

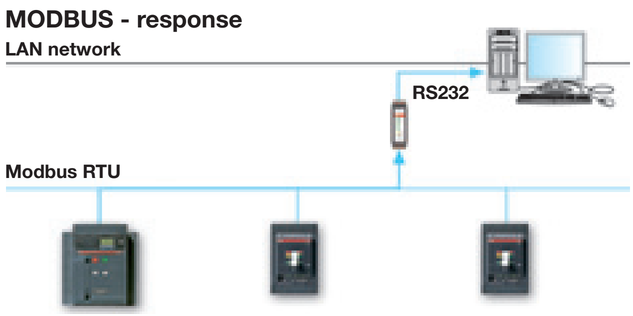
Under these suppositions, the query time for each circuit-breaker is about 59ms and, considering it constant for all the circuit-breakers, the polling time for each communication cycle shall be about: 59 × 6 = 354ms.

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.





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



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

4.4 SD-Testbus 2 and SD-View 2000 software programmes

4.4.1 SD-Testbus2.

SD-TestBus2 is ABB SACE installation and diagnosis free software for:

- starting of the Modbus network and of the relevant connected devices;
- detection of faults and anomalies in a network communication already functioning;
- testing, inspection and setting of the protection trip units and of the devices provided with Modbus communication functions.

SD-TestBu2 allows to:

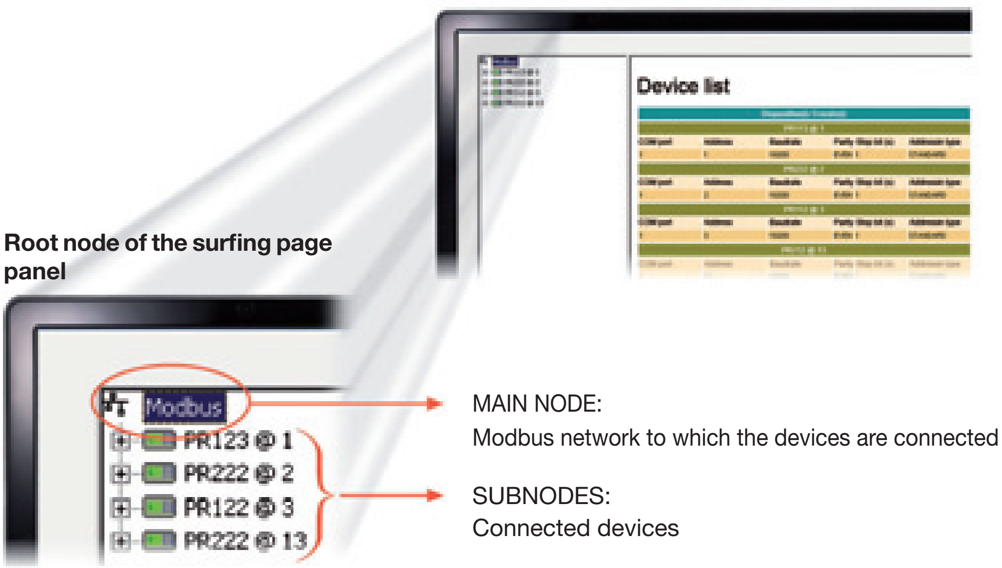
1) carry out a control and a complete scanning of the Modbus network in order to identify all the slave devices connected and to detect any possible error of connection or setting in the communication parameters (such as: address, parity, baud rate, parity check) of the circuit-breakers;

2) interact in real time, with the following devices:
- PR122/P and PR123/P with PR120D-M communication module;
- PR222DS/PD;
- PR223EF, PR223DS;
- PR332/P and PR333/P with PR330D-M communication module;
- SD030DX flex interfaces.

4.4.1.1 Scanning of the system bus

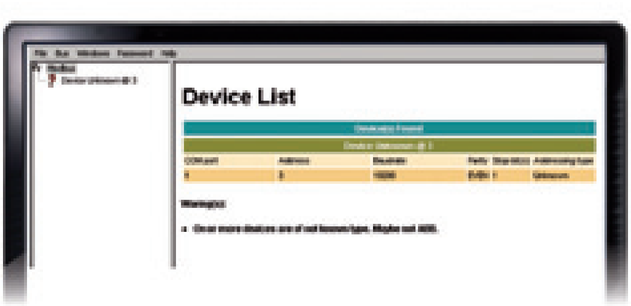
Thanks to this function, the software carries out an automatic scan of RS-485 bus and identifies all the slave devices present on the bus, pointing out their communication parameters. ABB devices are automatically recognized and are displayed both in the Device List as well as in the surfing page panel.

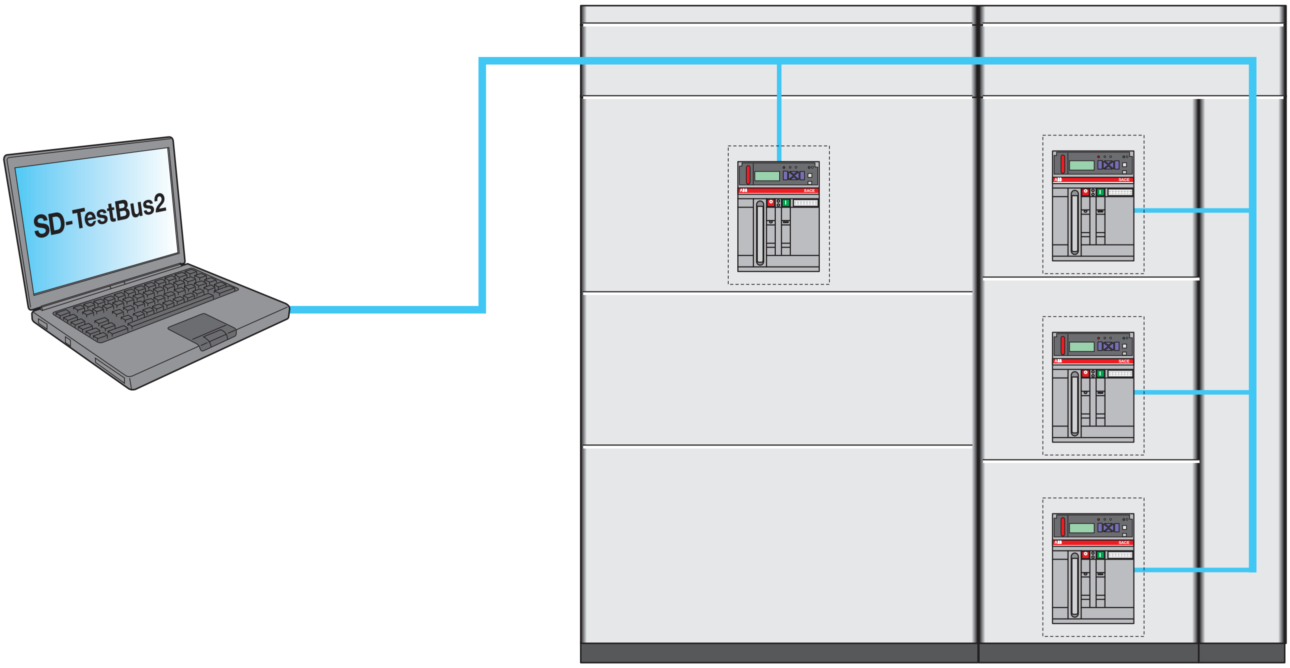
Figure 30: Window of SD-Testbus2 with the Device List and the surfing page panel



During the scanning process, the presence of every device, even if not a circuit-breaker, connected to the bus and able to communicate via Modbus protocol is detected and signaled with the relevant communication parameters.

At the end of the scanning operation, SD-Testbus2 displays any warning message about possible problems or configuration errors of the devices (e.g.: two devices with different transmission speed), allowing a complete diagnosis of the communication network.
Moreover, thanks to the function “Find Master”, SD-TestBus2 can monitor the presence of any master on the bus, showing its characteristic parameters of communication (COM port, speed and parity).
During the testing phase of an electric switchboard equipped with devices which communicate via Modbus and designed to be installed in a plant with supervision systems, scanning of the system bus is particularly useful.
In fact this control operation allows to identify any possible fault of connection between the different devices or setting errors of the communication parameters (e.g. speed, parity, stop bit number, etc.) or configuration errors of the connected devices (e.g. logic address), with the possibility to correct the errors when the switchboard is not in an operating phase yet.
Thanks to these verifications, if there is a fault in the communication with the supervision systems of the plant while the switchboard is put into service, this problem will not be imputed to the switchboard devices.





4.4.1.2 Interaction with the single device

For the circuit-breakers equipped with electronic trip units, the software provides some graphic pages through which it is possible to interact with them to:

- read the information and the data contained;
- send opening and closing commands;
- set the protection functions.

Here are some graphic pages.

- *Information*

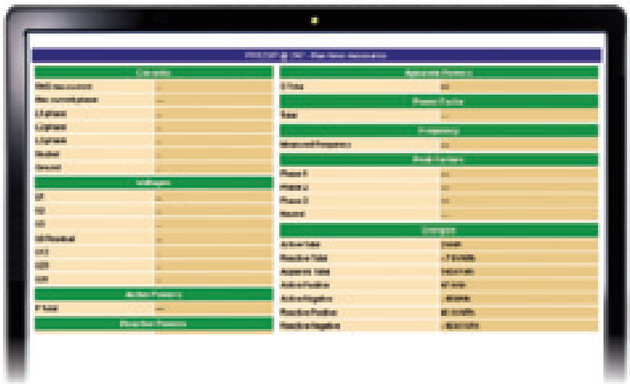
In this page it is possible to read the general information about the device (software release and circuit-breaker state) and send commands of opening, closing and wink. This last activates a blinking light on the front panel of the circuit-breaker, so that the operator can identify it.

When the device is set in local mode, the commands which can be present in the page are visualized in grey color and they cannot be activated.

- *Measures*

This page reports the measures acquired in real time by the trip unit; according to the type of trip unit installed the following measures can be taken:

- current;
- voltage;
- power and energy;
- power factor and frequency.



- *Measures History*

This page displays the measures recorded by the trip unit in the last hours. In particular:

- the phase at the maximum current
- the phase at the minimum and maximum voltage
- the medium and maximum active power
- the medium and maximum reactive power
- the medium and maximum apparent power

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

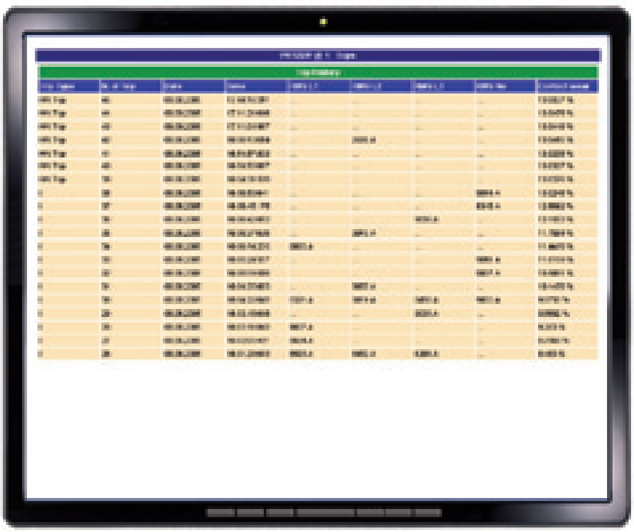
The function "Measures History" is available on the following trip units:

- PR122/P and PR123/P for Emax;
- PR332/P and PR333/P for Tmax T7 and Emax X1.

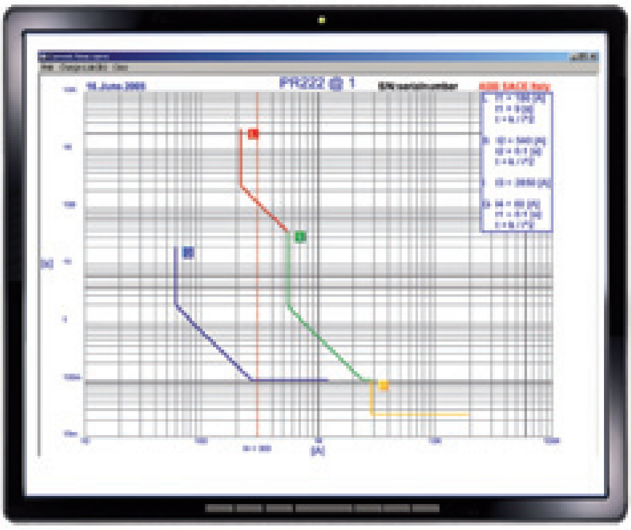
- Alarms
This page shows the protection alarms associated to the trip unit and the diagnostics alarms associated to the circuit-breaker.

- Settings
In this page it is possible to view and adjust the settings (thresholds and trip times) of the protection functions associated to a defined trip unit.

- Trips
In this page it is possible to get further information on the cause of the trip of one protection and get to know which type of protection has tripped. Some trip units allow also access to the information about previous trips



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



For more detailed information on the use of the software and on all the available functions please refer to the User Manual “SD-TestBus2”.

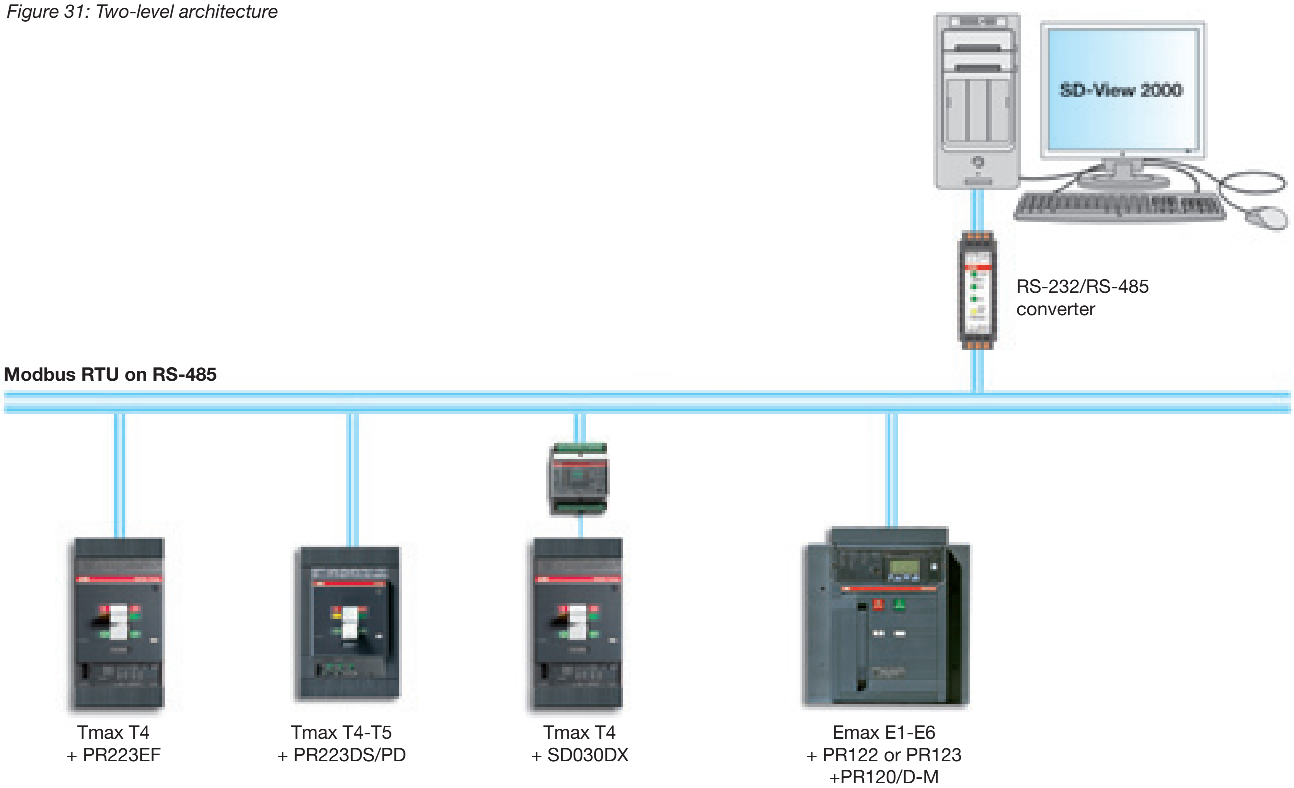
4.4.2 SD-View 2000

SD-View 2000 is a software for personal computers used for data acquisition, control and supervision of low voltage small and medium distribution plants with ABB equipment.
This software can be installed by the user, who is only required to know the installation characteristics (which and how many circuit-breakers are installed and how they are connected to each other) and to insert the addresses and the typologies of the units to be controlled.
This software recognizes the devices connected and configured (through the Modbus address) and shows the graphic pages already configured for each of them.
It is also possible to recognize automatically the units installed and connected to the bus, by passing directly to the putting in service without carrying out any configuration.

The installation of SD-View 2000 allows using the personal computer as SCADA of a supervision system with two-level architecture:
1) Control level
   Personal computer on which SD-View2000 is installed.
2) Field level
   ABB devices connected to the bus Modbus RS-485.

The personal computer can use at most 4 serial ports and each of them can be connected to 31 devices. For the supervision and control of the electrical plant, the PC is used as operator station, from which data can be viewed and printed, commands can be sent to the devices and all the operations necessary for the management of the plant can be carried out.

Figure 31: Two-level architecture

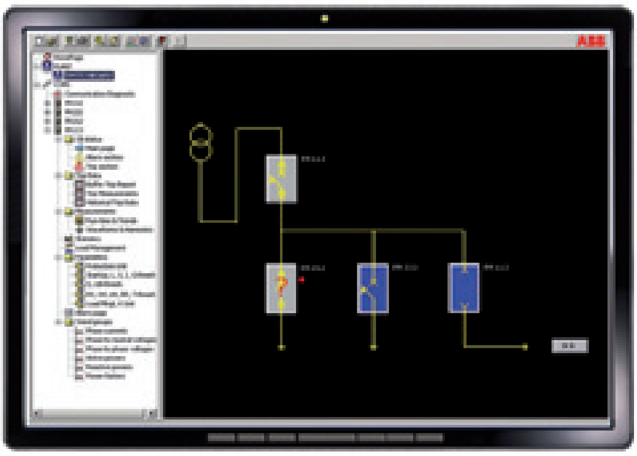


Supervision of the electrical plant

With SD-View 2000 it is possible to have under control the situation of the plant at all times and to be able to control all the functions in an easy and immediate way.
The operator station (personal computer on which SD-View 2000 is installed) makes it possible to receive information from the installation and to control the circuit-breakers by acting on the relevant trip units.

Thanks to the synoptic panel of the installation it is possible to view the whole distribution network and to control the operation state through symbols representing the state of the protective devices (open/closed/tripped, racked-in/racked-out) and the presence of alarm situations.

Figure 32: SD-View 2000 synoptic panel of the installation



Thus the possible supervision and remote control operations are:

- sending of opening and closing commands to the circuit-breakers;
- reading of the installation electrical values (current, voltage, power factor, power);

- reading and modification of the trip characteristics of the protection units;
- detection of the state of the apparatus (open, closed, number of operations, trip for fault);
- detection of anomalous operating situations (e.g. overload) and, in case of protection tripping, information about the type of fault (short-circuit, overload, earth fault) and value of the interrupted currents;
- storage of the plant history (energy consumption, most loaded phase, any possible warning of anomalies or faults);
- graphic representation of the temporal evolution of the plant.

This and other information are available for the operator through user friendly graphic pages, which allow the user to manage the data coming from each circuit-breaker.

Connectable devices

SD-View 2000 can manage all ABB low voltage circuit-breakers provided with Modbus communication, both new as well as belonging to previously designed product families; among them:

- Emax air-circuit breakers from E1 to E6 (see clause 4.1.1);
- Emax X1 air circuit-breakers (see clause 4.1.2);
- Tmax T7 moulded-case circuit-breakers (see clause 4.1.2);
- Tmax moulded-case circuit-breakers type T4, T5 and T6 (see clause 4.1.3);

and SD030DX Flex Interfaces to interface the air and moulded-case circuit-breakers, equipped with thermomagnetic trip unit or basic electronic trip unit, and air or moulded-case switch-disconnectors (see clause 4.2).

All the characteristics of the connectable devices are preconfigured in the system. The user does not need to set configurations, neither to load tables showing the data to be displayed for each trip unit, or to create graphic pages; it is sufficient for him to load into the system only a list of the connected devices.

The graphic pages relevant to each circuit-breaker are particularly direct and easy to use, as shown in Figure 33.

Figure 33: Main graphic page of an Emax air circuit-breaker

For more detailed information on the installation and the use of the software please refer to the User Manual “SD-View 2000 Supervision System”.

4.5 Example of product selection for supervision and remote control

Take into consideration a low voltage distribution plant with a supervision system of the same type as shown in Figure 34.

The supervision system uses a bus network with Modbus RTU protocol on RS-485.

At the control level there is a personal computer with the software SD-View 2000 by ABB SACE[9].

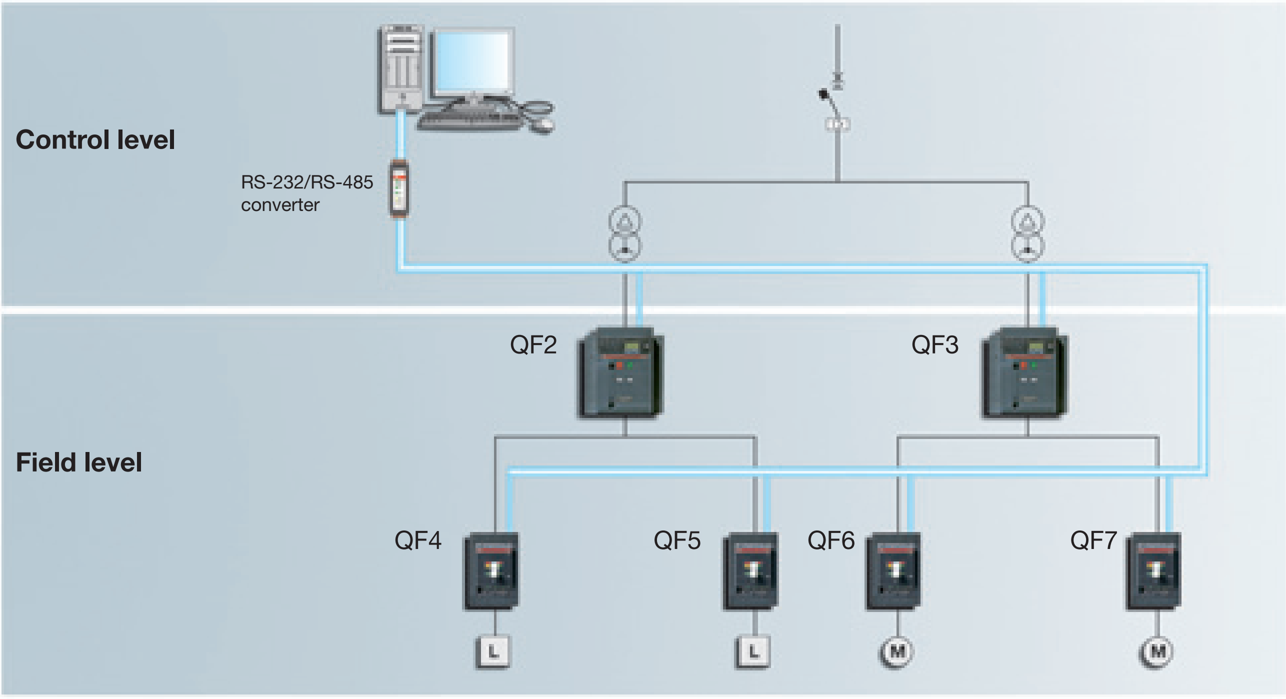
The personal computer works as a SCADA system, acquiring, processing and storing the data sent by all the circuit-breakers.

The field level is constituted by the protection circuit-breakers, Tmax moulded-case and Emax air circuit-breakers, equipped respectively with electronic microprocessor-based trip units type:

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

[9] *See clause 4.4.2.*

Figure 34: Supervision and control system of a LV distribution plant



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).
- *Tmax T4 molded-case circuit-breakers (QF4, QF5, 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 power supply Vaux (see Annex B).

Choice of products and accessories for remote control
To perform circuit-breaker remote control the following accessories are necessary:

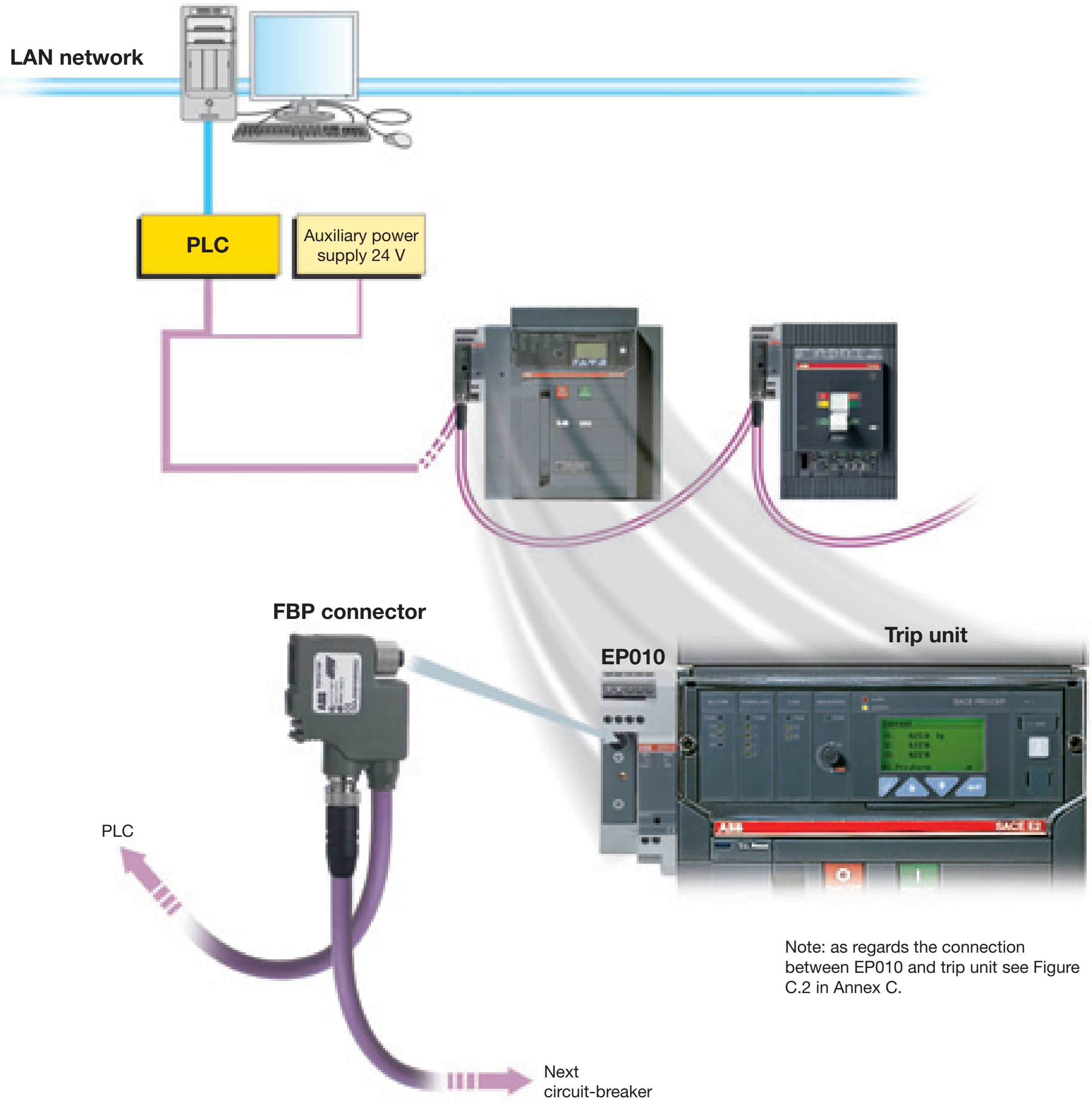
- *For Emax E1 air circuit-breakers (QF2 and QF3):*
  1) shunt opening release (YO)
  2) shunt closing release (YC)
  3) geared motor for the automatic charging of the closing springs (M)
- *For Tmax T4 molded-case circuit-breakers (QF4, QF5, QF6 and QF7):*
  1) motor operator with MOE-E module (see Annex E)
  2) AUX-E auxiliary contacts in electronic version (provided by default with MOE-E).

4.6 Circuit-breakers integration in Profibus DP or DeviceNet fieldbus

Fieldbus EP010 interface unit allows the integration of ABB SACE circuit-breakers in communication systems with Profibus DP or DeviceNet protocol.
To get this result ABB intelligent connectors FBP Field-BusPlug, which allow the communication with the different protocols, are used.
The connection of the circuit-breakers to the fieldbus is realized 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 more different applications, thus combining the control of a process with the control of the electrical distribution plant which supplies it.



Note: as regards the connection between EP010 and trip unit see Figure C.2 in Annex C.

4.6.1 Supervision and remote control

4.6.1.1 Emax air circuit-breakers E1-E2-E3-E4-E6

ProfibusDP and DeviceNet: supervision and remote control

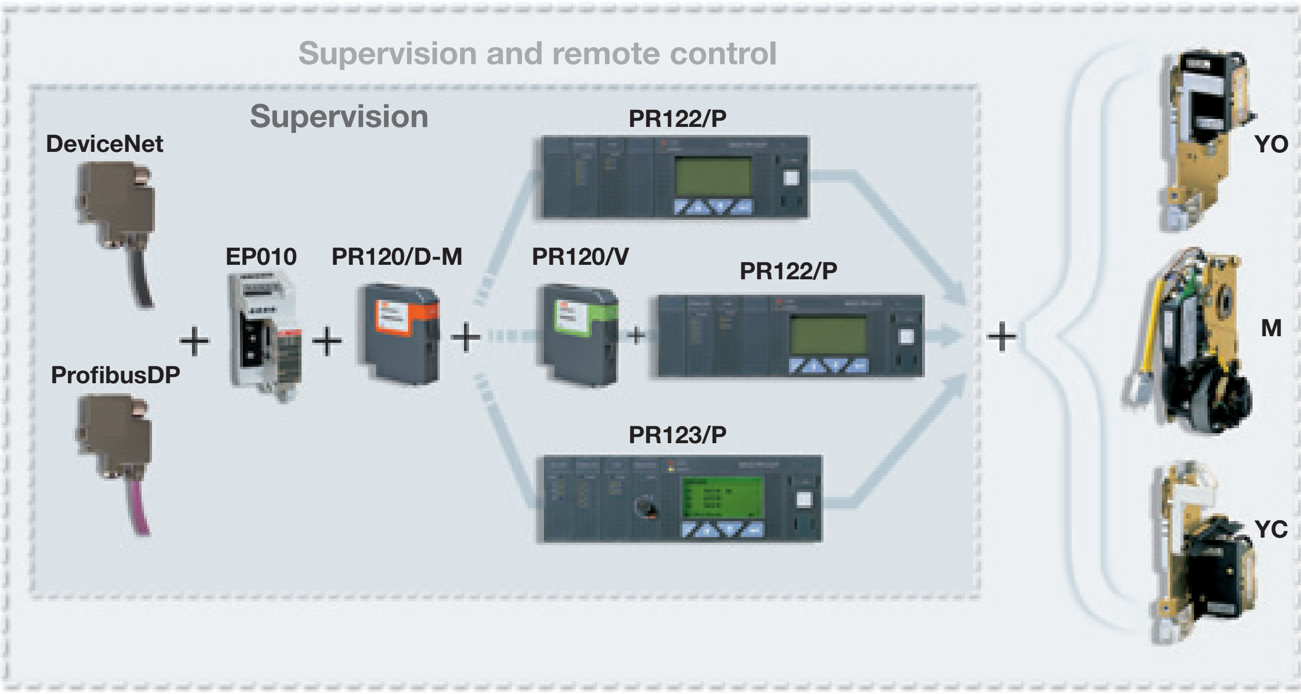
Emax air circuit-breakers equipped with electronic trip units type PR122/P e PR123/P are connected to EP010 unit through PR120/D-M communication module as shown in Annex C.

The power supply at 24 Vd.c. for EP010 is delivered through the FBP connector, which provides also bus communication.
The trip unit connected to EP010 must be supplied with the auxiliary power supply Vaux (for the electrical characteristics see Annex B).

The interface of the circuit-breakers with the field bus is implemented through the suitable FBP connector:
- PDP22-FBP for ProfibusDP;
- DNP21-FBP for DeviceNet.

- Electronic trip units type PR122/P and PR123/P
For information about the measures, data and alarms made available by the electronic trip units type PR122/P and PR123/P in the following configurations see Table A.3 of Annex A.

For the remote control operations which can be performed on the circuit-breaker see Table A.3 of Annex A at the entry Commands.
All the commands from remote control (through the bus) can be disabled by setting the trip unit to local mode.



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

Profibus DP and DeviceNet: supervision and remote control

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

The power supply at 24 Vd.c. for EP010 is delivered through the FBP connector which provides also bus communication.

The trip unit connected to EP010 must be supplied with the auxiliary power supply Vaux (for the electrical characteristics see Annex B).

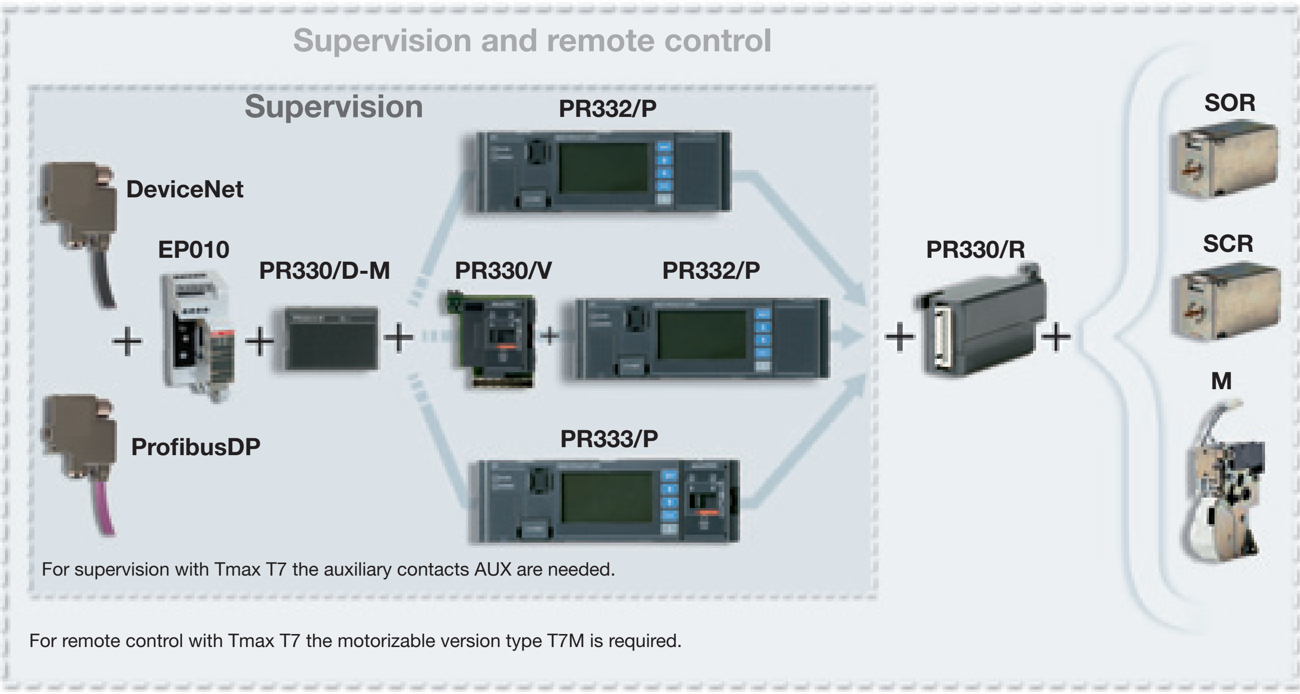
The interface of the circuit-breakers with the field bus is implemented through the suitable FBP connector:
- PDP22-FBP for ProfibusDP;
- DNP21-FBP for DeviceNet.

- Electronic trip units type PR332/P and PR333/P

For information about the measures, data and alarms made available by the electronic trip units type PR332/P and PR333/P in the following configurations see Table A.3 of Annex A.

For the remote control operations which can be performed on the circuit-breaker see Table A.3 of Annex A at the entry Commands.

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



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

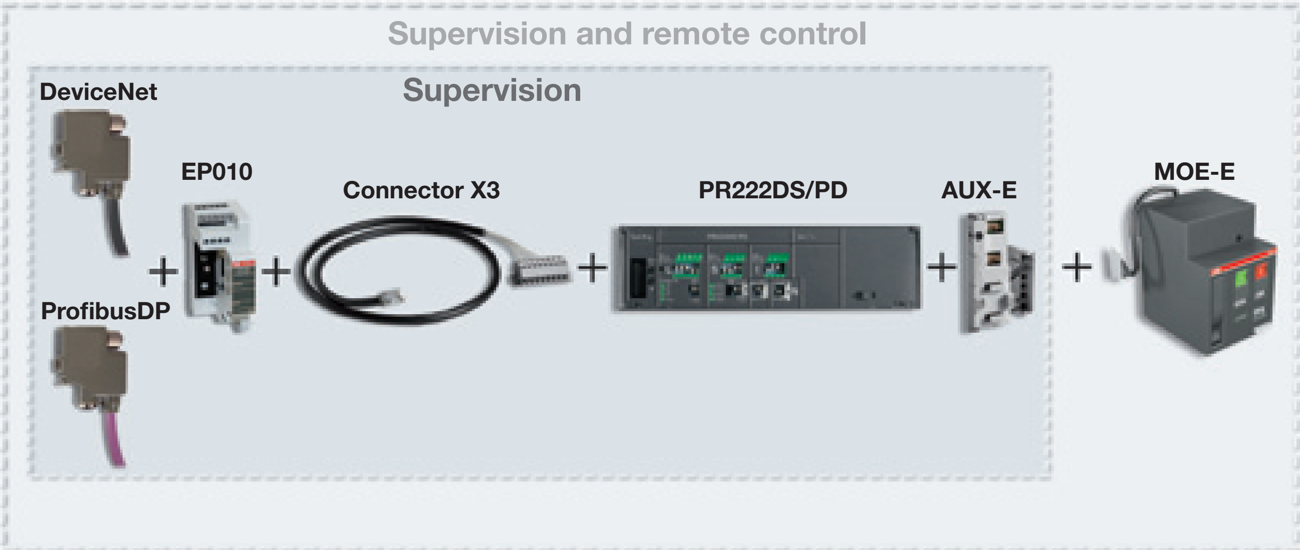
ProfibusDP and DeviceNet: supervision and remote control
Tmax moulded-case circuit-breakers type T4, T5 and T6 equipped with the electronic trip units PR222DS/PD, PR223EF and PR223DS are connected to EP010 unit through X3 rear connector as shown in Annex C.
The power supply at 24 Vd.c. for EP010 is delivered through the FBP connector which provides also bus communication.
The trip unit connected to EP010 must be supplied with the auxiliary power supply Vaux (for the electrical characteristics see Annex B).
The interface of the circuit-breakers with the field bus is implemented through the suitable FBP connector:
- PDP22-FBP for ProfibusDP;
- DNP21-FBP for DeviceNet.

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

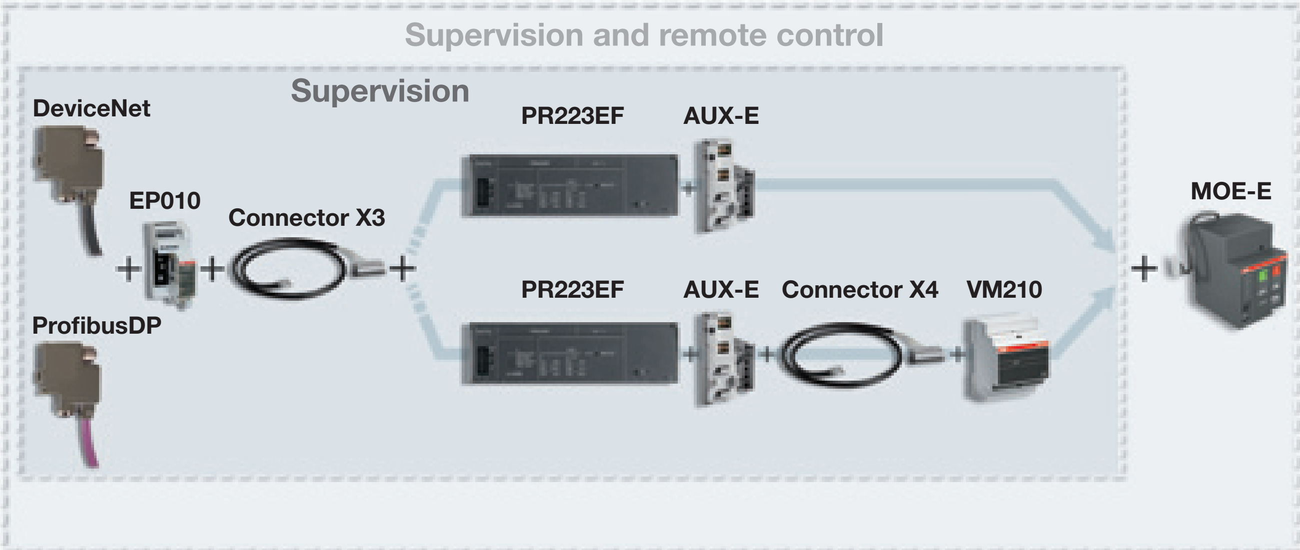
For information about the measures, data and alarms made available by the electronic trip units type PR222DS/PD, PR223EF and PR223DS in the following configurations see Table A.4 of Annex A.

For the remote control operations which can be performed on the circuit-breaker see Table A.4 of Annex A at the entry Commands.
All the commands from remote control (through the bus) can be disabled by setting the trip unit to local mode.

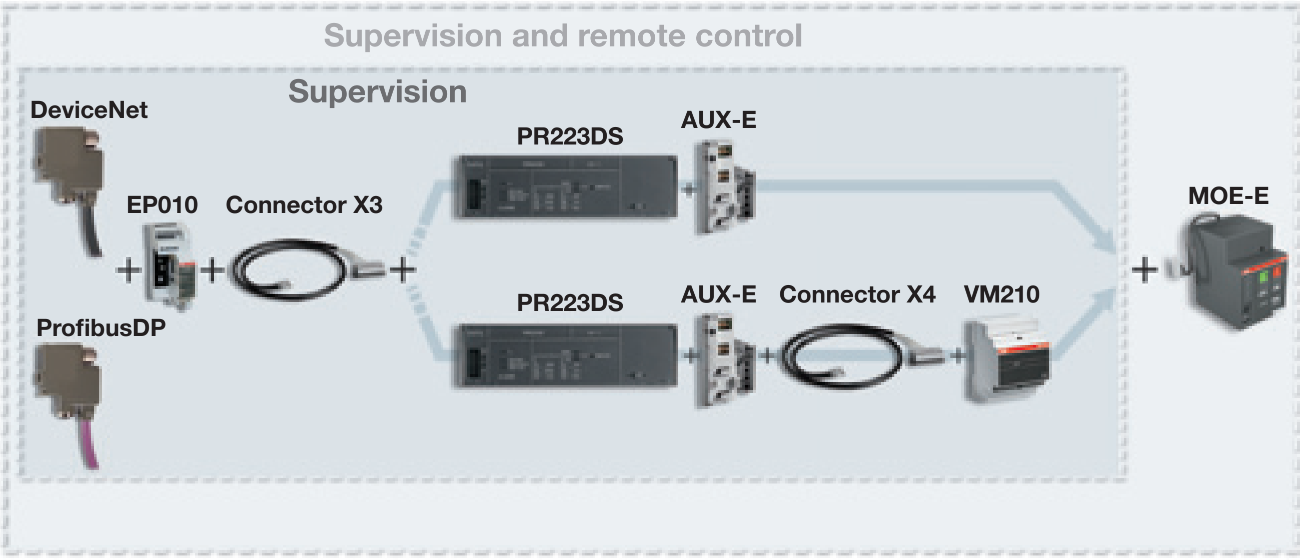
- PR222DS/PD electronic trip unit



- PR223EF electronic trip unit



- **PR223DS electronic trip unit**



NOTE: For further information about the dialogue functions and the features of the products described in this chapter, reference shall be made to the relevant technical catalogues and the product manuals

5 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.

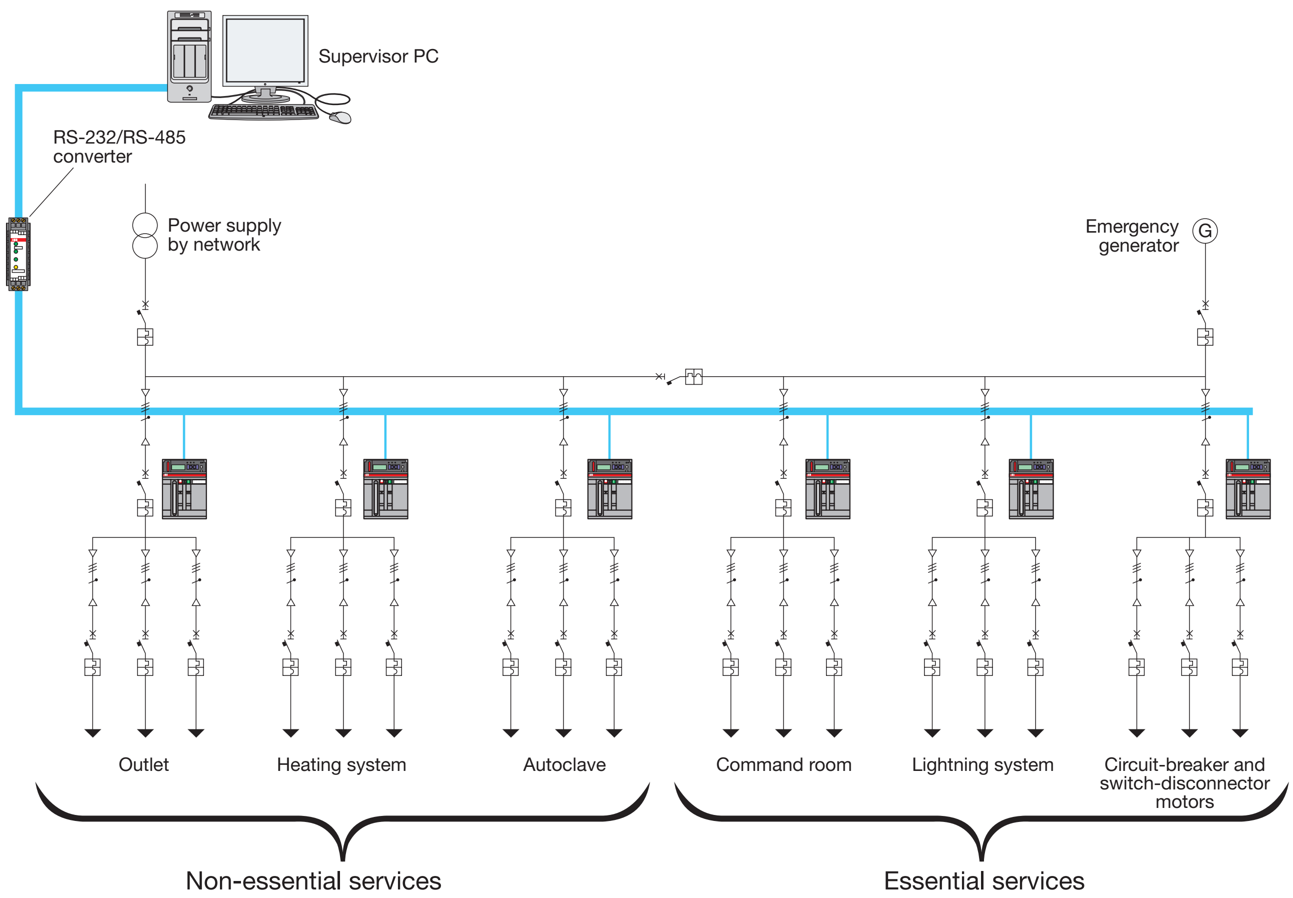
5.1 Supervision of protections and circuit-breaker switching

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 36: 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.

5.2 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.

5.2.1 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 use as main circuit-breaker an Emax E2 equipped with the following accessories:

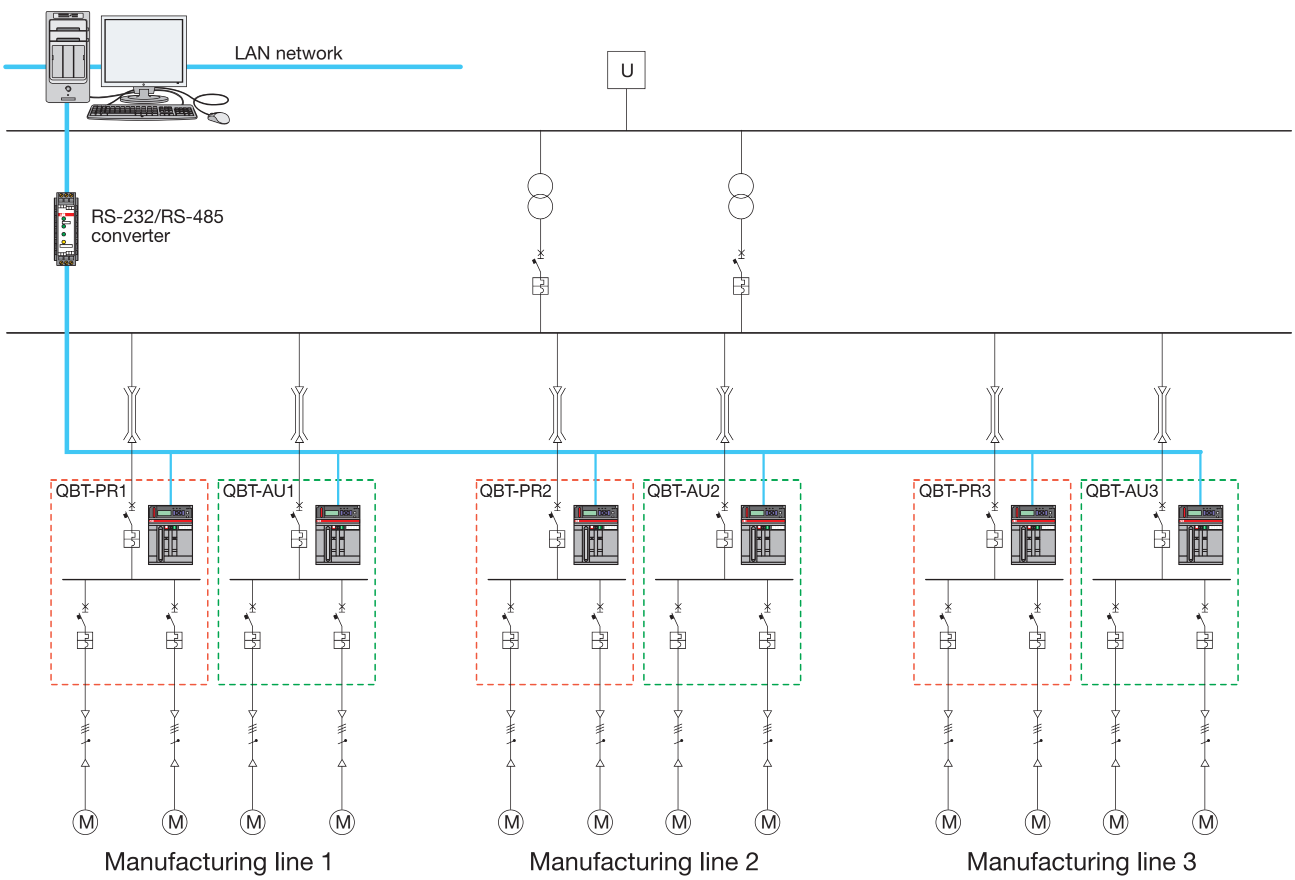
- PR122/P trip unit;
- PR120/V voltage measuring module;
- PR120/D-M Modbus communication module.

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 shielded cable, to the 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.

5.2.2 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 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.



5.3 Management of priority and non-priority loads

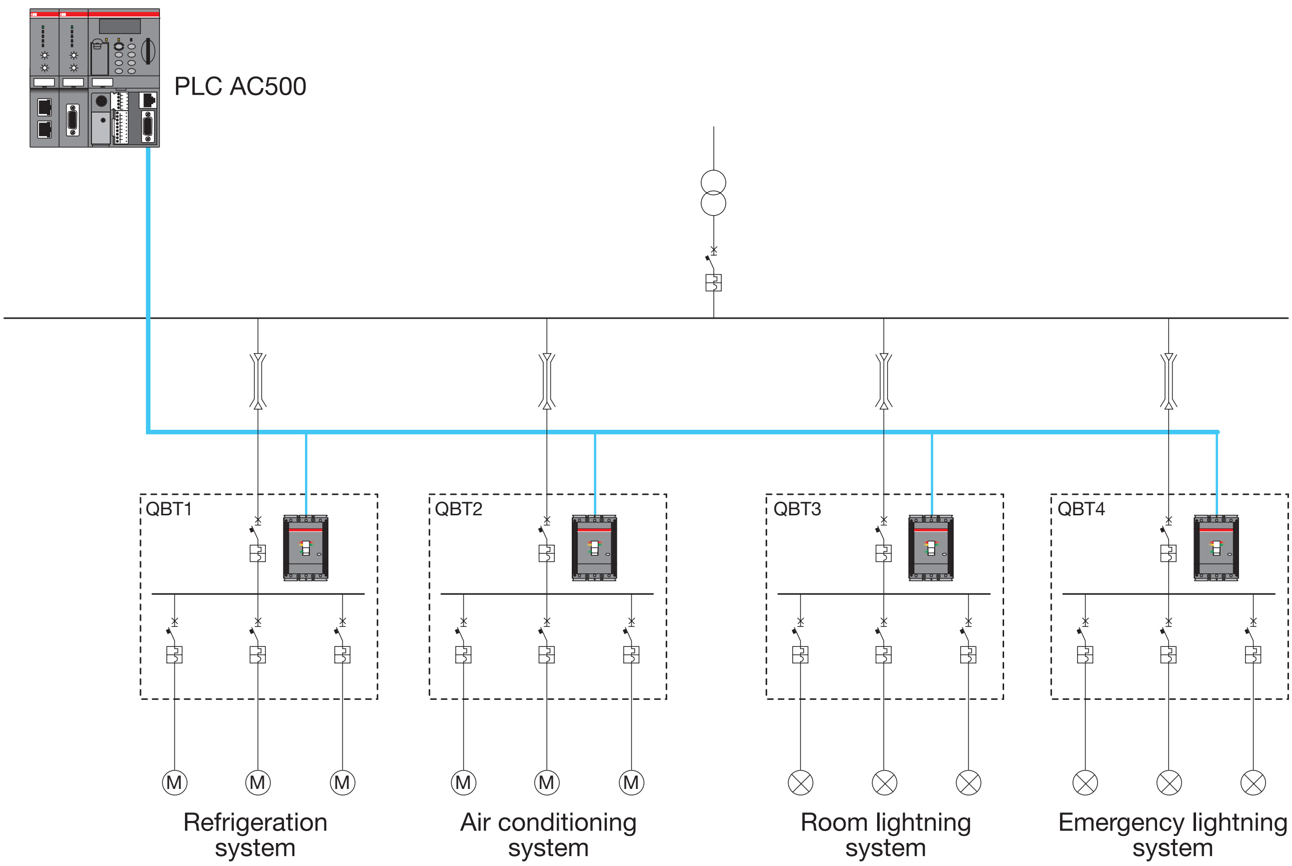
In a shopping mall there are various refrigerating rooms, each of them equipped with independent refrigeration system. The refrigeration system of each room is provided with its own thermostat and starts automatically and independently.
Moreover, each refrigeration system is able to run in normal mode (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 of each sub-distribution switchboards QBT1, QBT2, QBT3 and QBT4 are series Tmax provided with PR222DS/PD (with Modbus communication interface).

Moreover, each circuit-breaker is equipped with auxiliary contacts with electronic interface AUX-E 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 and position (open/closed, racked-in/out)	■	■	■	■	■	■
	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	■	■	■	■	■	■
	Setting of protection curves and thresholds	■	■	■	■	■	■
	Time synchronization of each circuit-breaker carried out by system	■	■	■	■	■	■
Events	Changes of state of the circuit-breaker, of the protections and of all the alarms (the last 80)	■	■	■	■	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following document:
- Instruction manual PR122-3/P+PR120/DM-PR332-3/P+PR330/DM Modbus System Interface.

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	■	■	■	■	■
	Data records of the last n trips	1	20	20	20	20
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		■	■		
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	Changes of state of the circuit-breaker, of the protections and of all the alarms	■	■	■	■	■

For further information about the electric quantities, the data and the alarms available, reference must be made to the following documentation:
- Instruction manual PR223EF Modbus System Interface
- Instruction manual PR223DS Modbus System Interface
- Instruction manual PR222DS/PD Modbus System Interface.

Supervision with fieldbus Profibus DP and DeviceNet

Table A.3: 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, racked-out)	■	■	■	■	■	■
	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	■	■	■	■	■	■

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

Table A.4: 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	PR223DS + EP010	PR223DS + 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			■		■
	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 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)	■	■	■	■	■
	Alarms reset	■	■	■	■	■
Events	Changes of state of the circuit-breaker, of the protections and of all the 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

Annex B: Electrical characteristics of the auxiliary power supply

Emax air circuit-breakers: E1, E2, E3, E4 and E6

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

* Value referred to the supply of: PR12X/P+ PR120/D-M communication module

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

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

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

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

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

As regards the air circuit-breakers type Emax and 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 and K2.
As regards the moulded-case circuit-breakers type 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 PR223DS trip unit

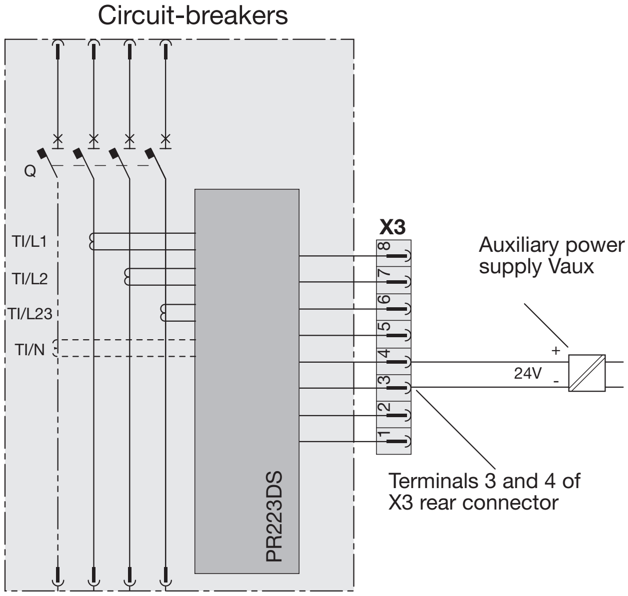
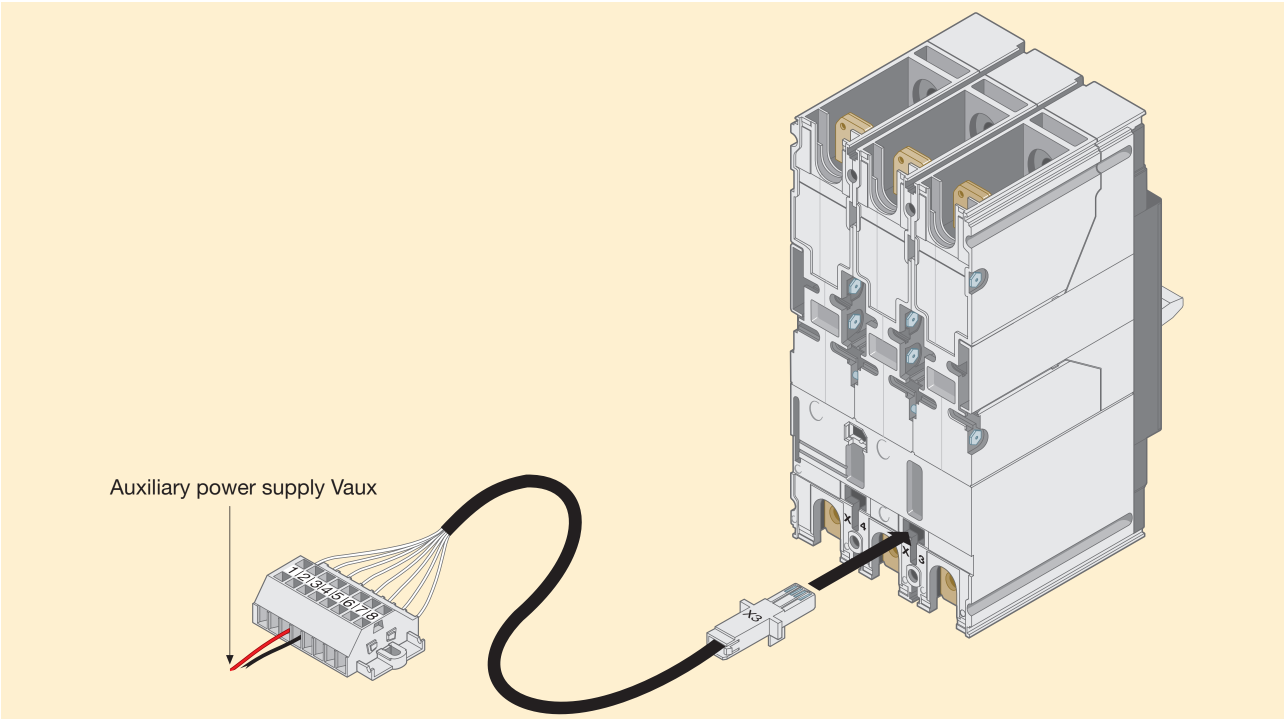


Figure B.2: Auxiliary power supply for moulded-case circuit-breakers T4, T5 and T6



Annex B: Electrical characteristics of the auxiliary power supply

Annex C: The communication modules

Emax air circuit-breakers E1, E2, E3, E4 and E6

- PR120/D-M communication module

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

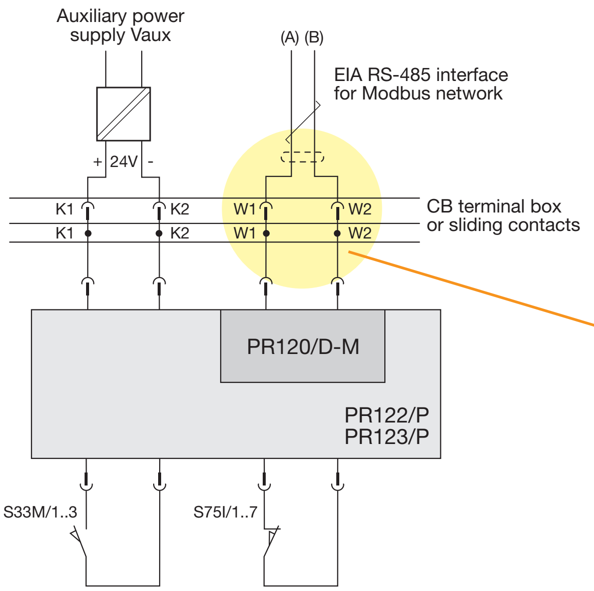
The communication module is supplied directly through PR122/P or PR123/P trip unit, which in its turn is supplied by the auxiliary power supply Vaux. The relevant technical data are shown in the following table.

	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

- Connection to the Modbus network

PR122/P and PR123/P 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

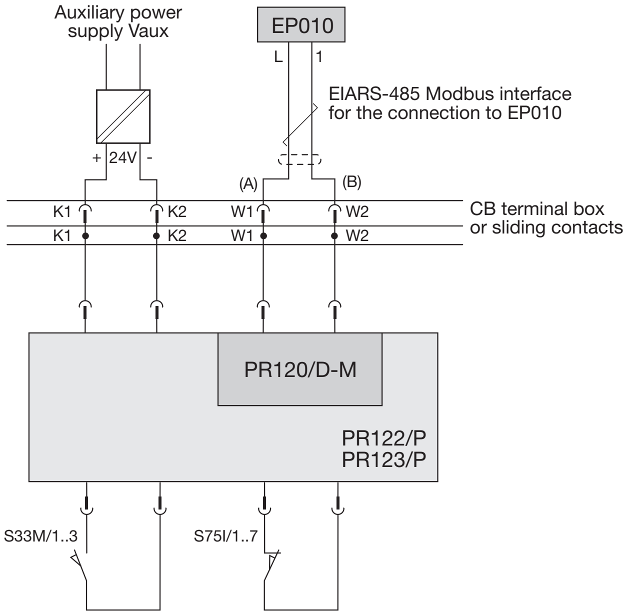


Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for auxiliary power supply Vaux
S33M/1..3: contacts signaling spring charged
S75I/1..7: contacts signaling circuit-breaker racked-in (for CBs in withdrawable version)

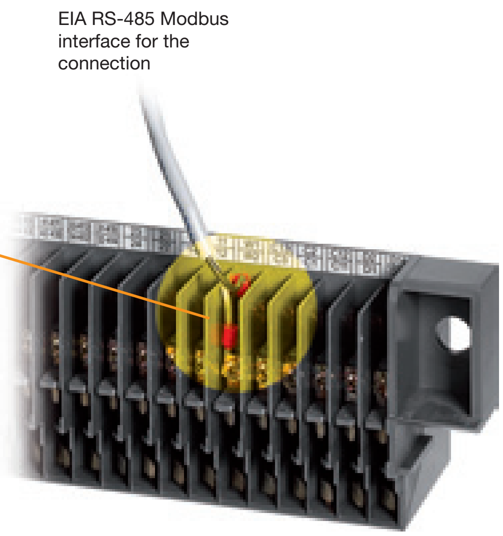
- Connection to EP010 unit

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)



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

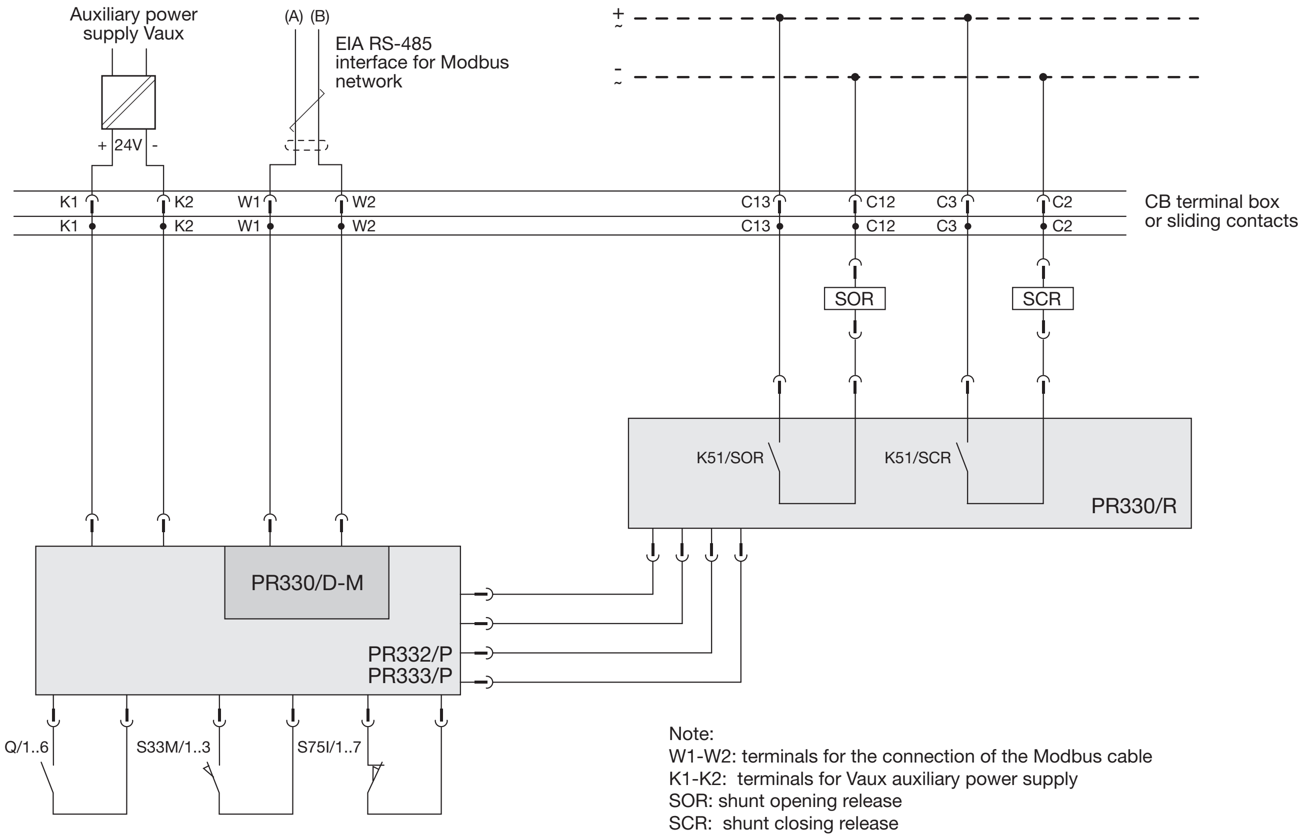
- PR330/R actuator module

Emax X1 and Tmax T7 circuit-breakers can operate opening and closing commands from remote control when, together with PR330/D-M communication module, 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.

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

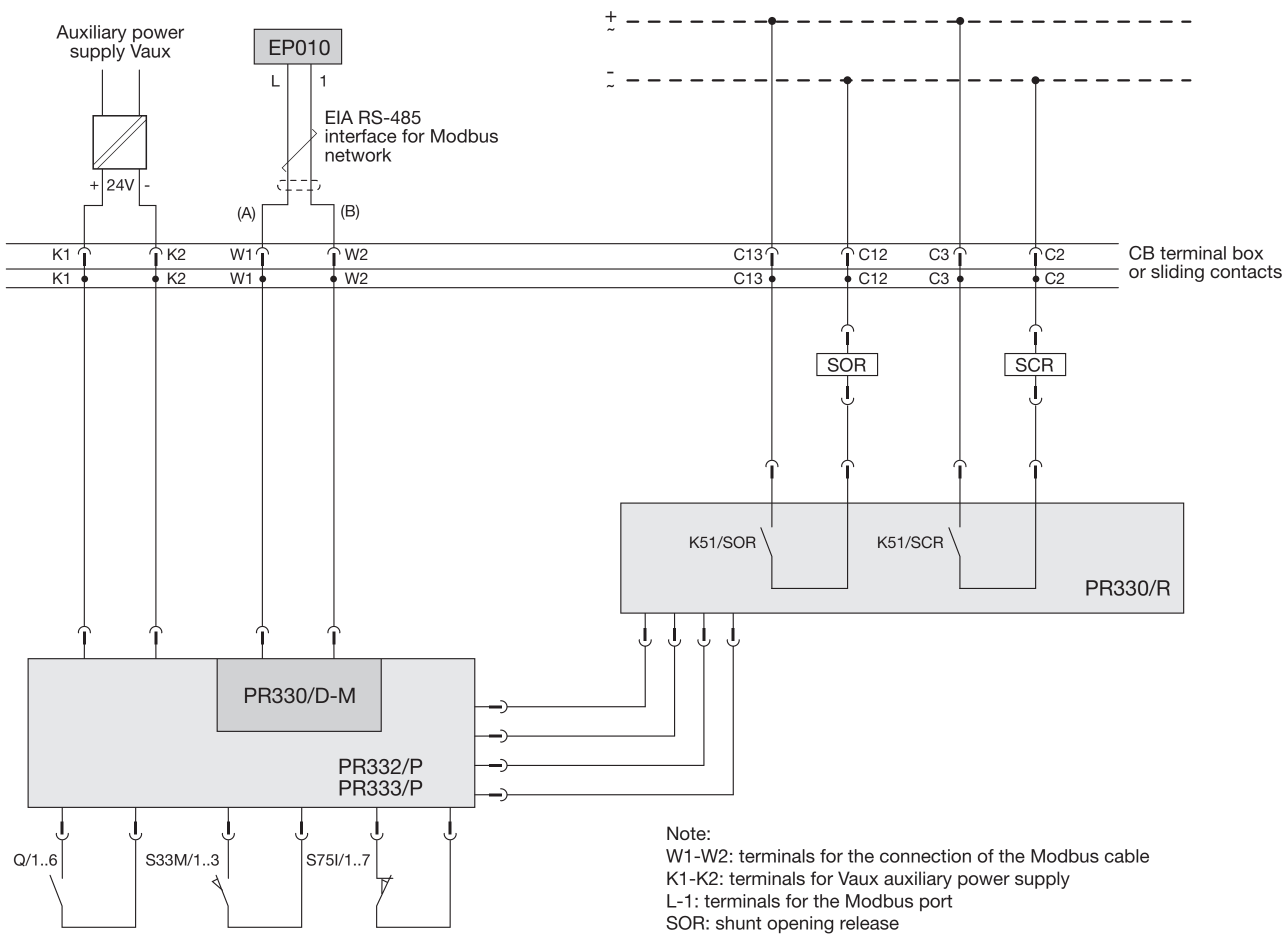


Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for Vaux auxiliary power supply
SOR: shunt opening release
SCR: shunt closing release
K51/SOR: control contact for the shunt opening release
K51/SCR: control contact for the shunt closing release
Q/5-Q/6: circuit-breaker auxiliary contacts
S33M/1..3: contacts signaling spring charged
S75I/1..7: contacts signaling circuit-breaker racked-in
(for CBs in withdrawable version)

- 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



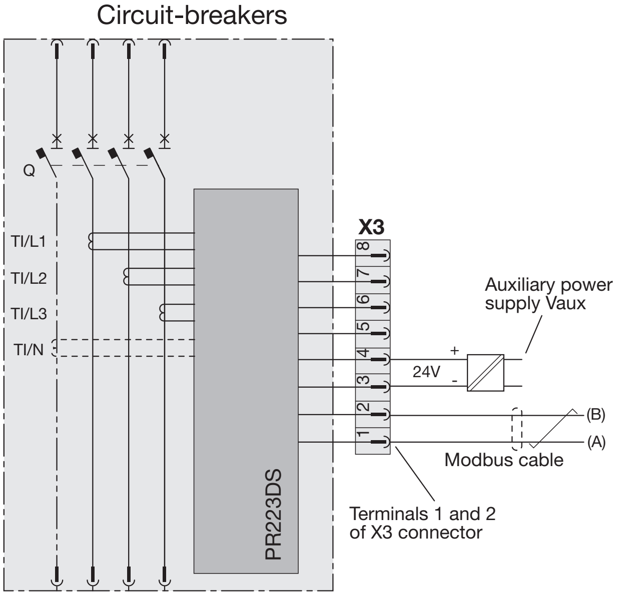
Note:
W1-W2: terminals for the connection of the Modbus cable
K1-K2: terminals for Vaux auxiliary power supply
L-1: terminals for the Modbus port
SOR: shunt opening release
SCR: shunt closing release
K51/SOR: control contact for the shunt opening release
K51/SCR: control contact for the shunt closing 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)

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

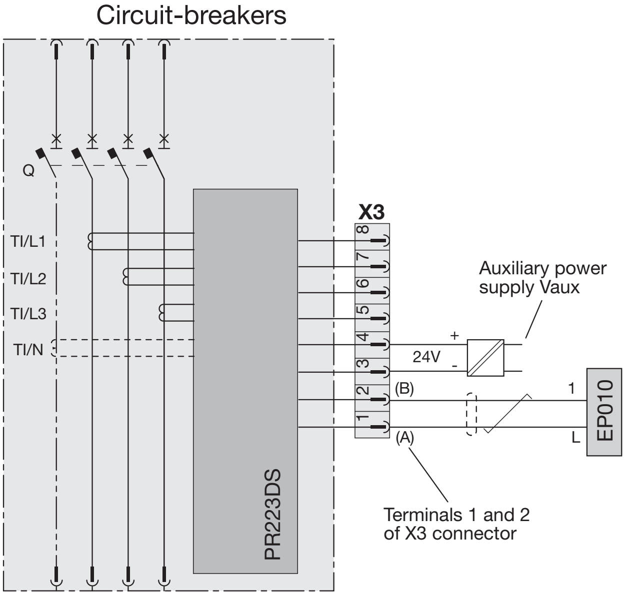
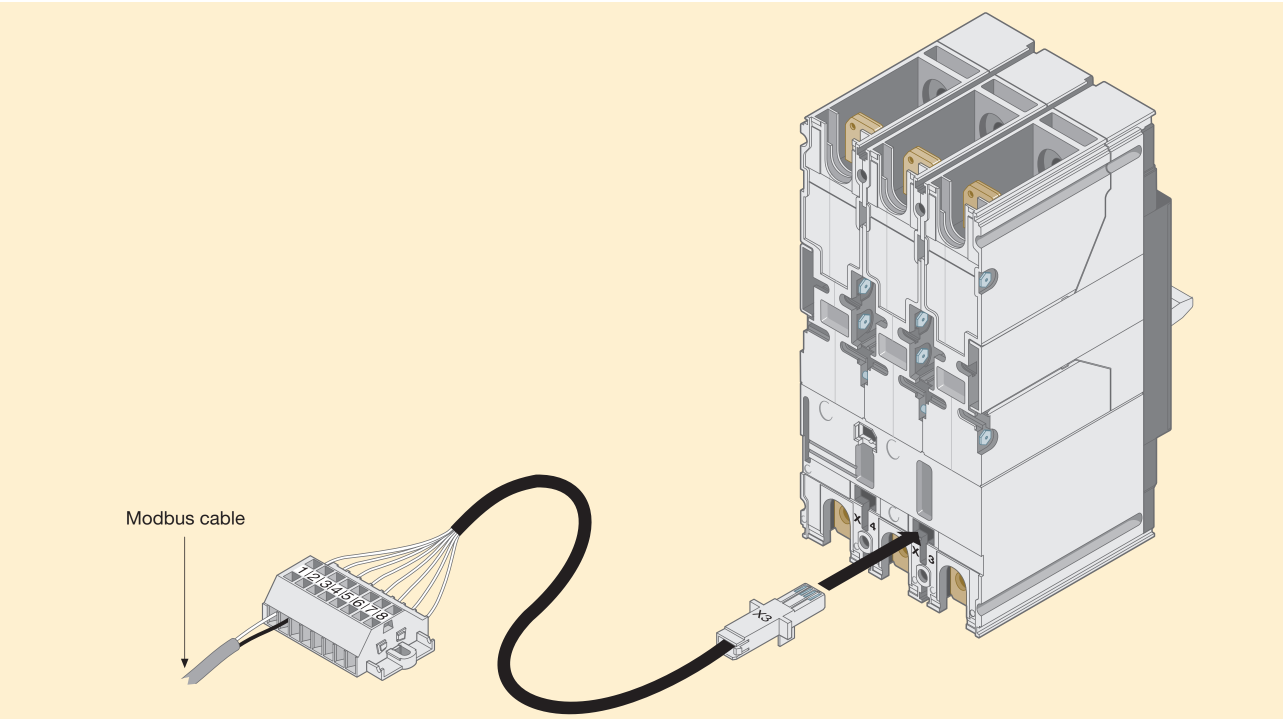


Figure C.6: Connection to the Modbus network of Tmax CBs T4, T5 and T6 through X3 connector



Annex D: The measuring modules

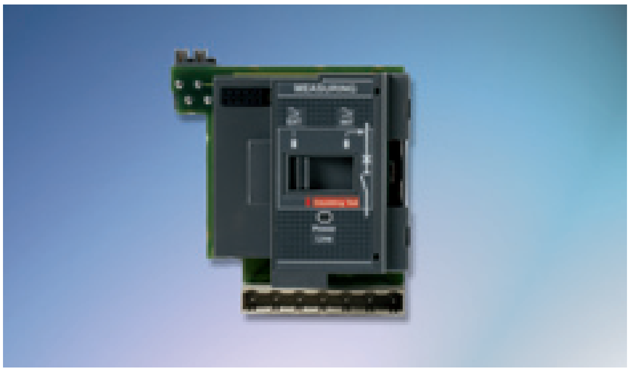
Emax air circuit-breakers E1 to E6 with PR120/V measuring module and X1 air circuit-breaker and Tmax T7 moulded-case circuit-breaker with PR330/V measuring module

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.

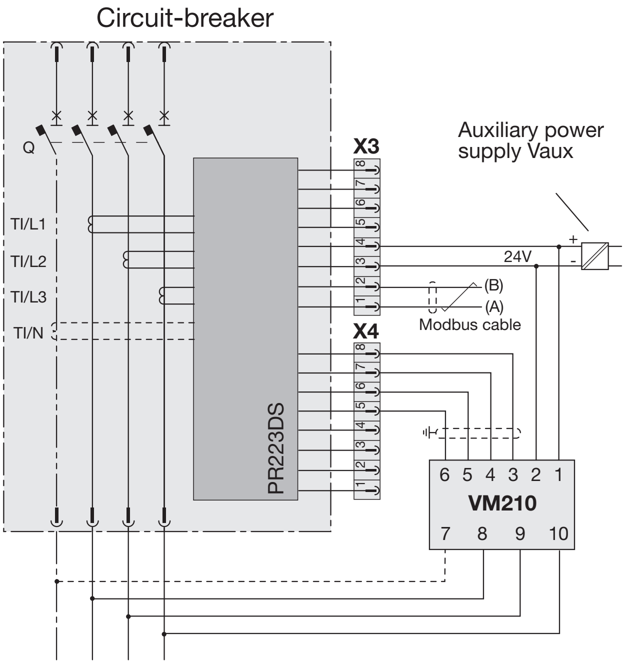
Figure D.3: VM210 measuring module

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

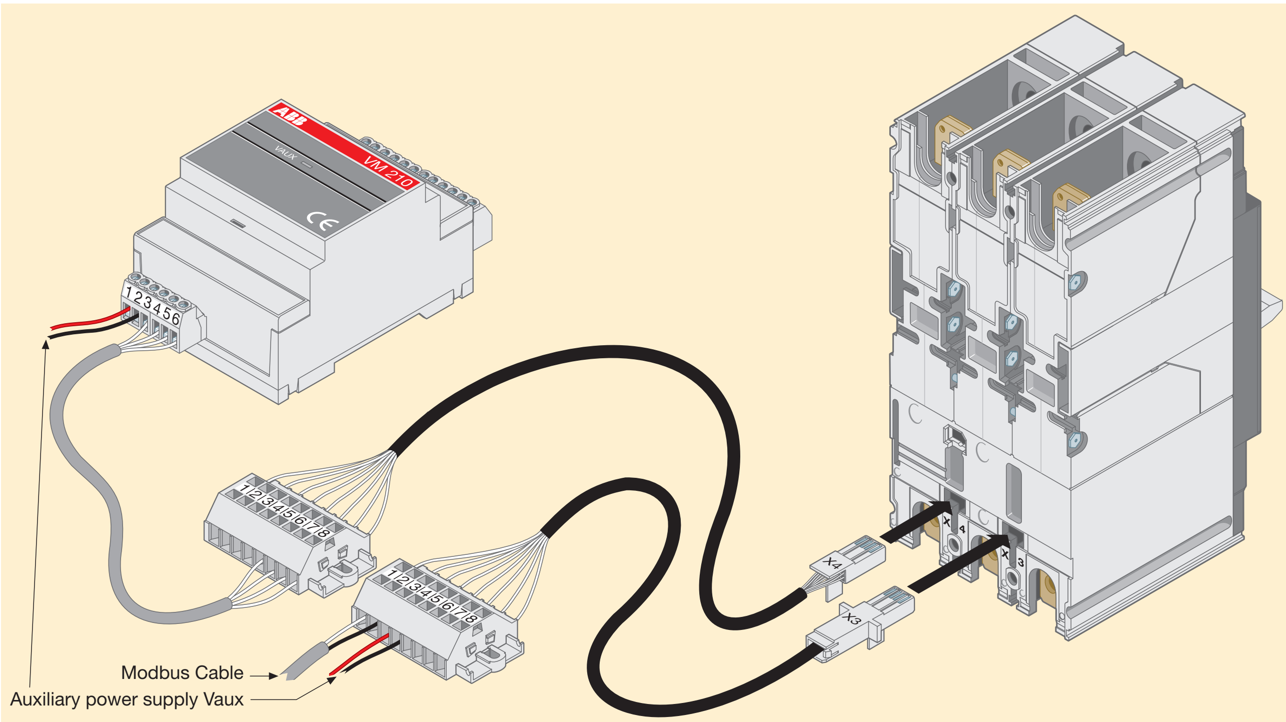


VM210 Connection table

	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

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



Annex E: AUX-E auxiliary contacts and MOE-E motor operator

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

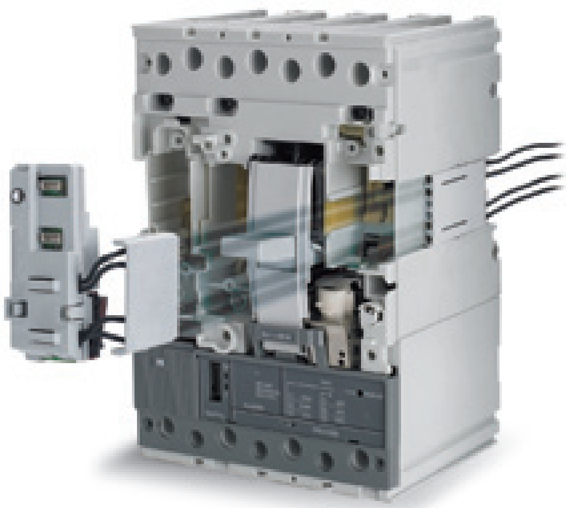
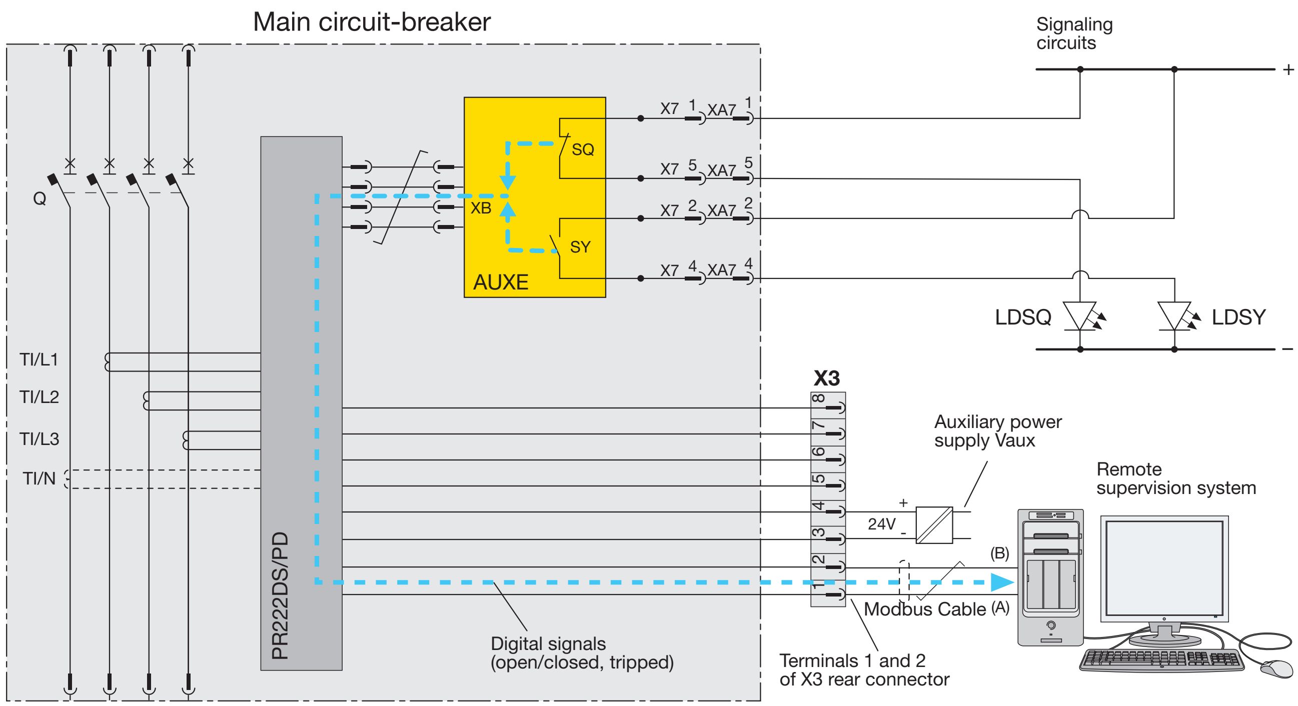


Figure E.2: Wiring diagram of AUX-E contacts connected to PR222DS/PD



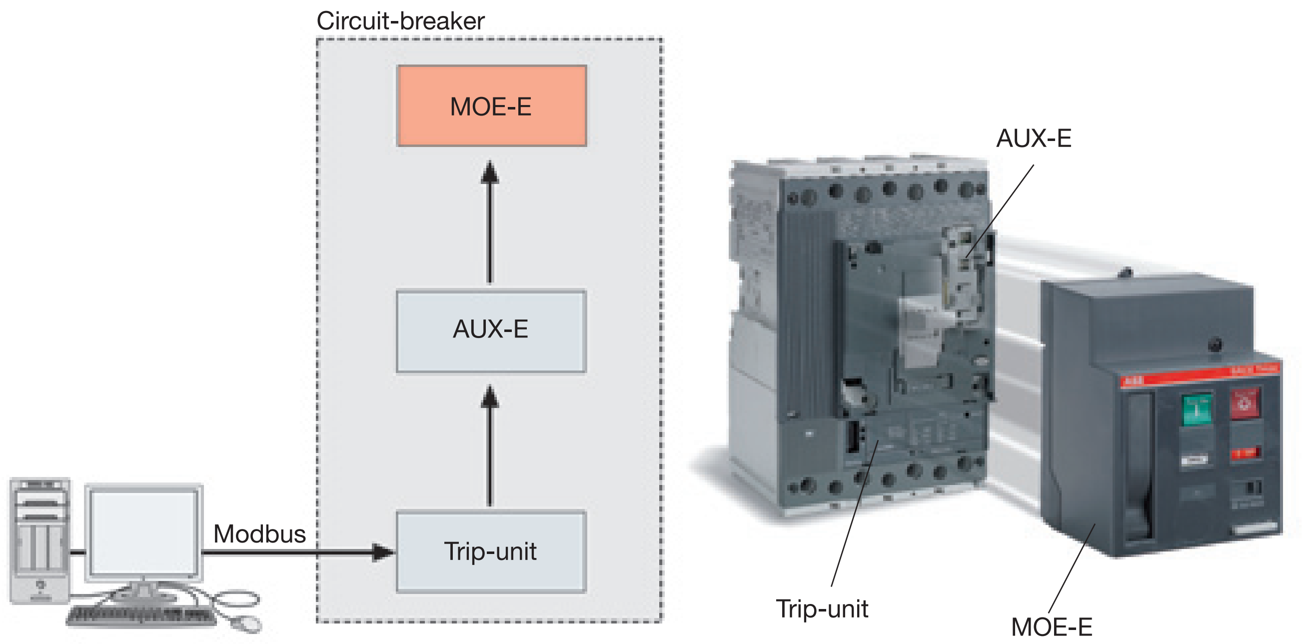
Note:
SQ: Contact for the electrical signaling of circuit-breaker open/closed
SY: Contact for the electrical signaling of circuit-breaker open (tripped position)

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).

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



Annex F: The parity bit

The parity bit is an additional control bit placed in queue after each transmitted character to avoid errors in reception.
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.

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Due to possible developments of standards as well as of materials, the characteristics and dimensions specified in this document may only be considered binding after confirmation by ABB SACE.

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