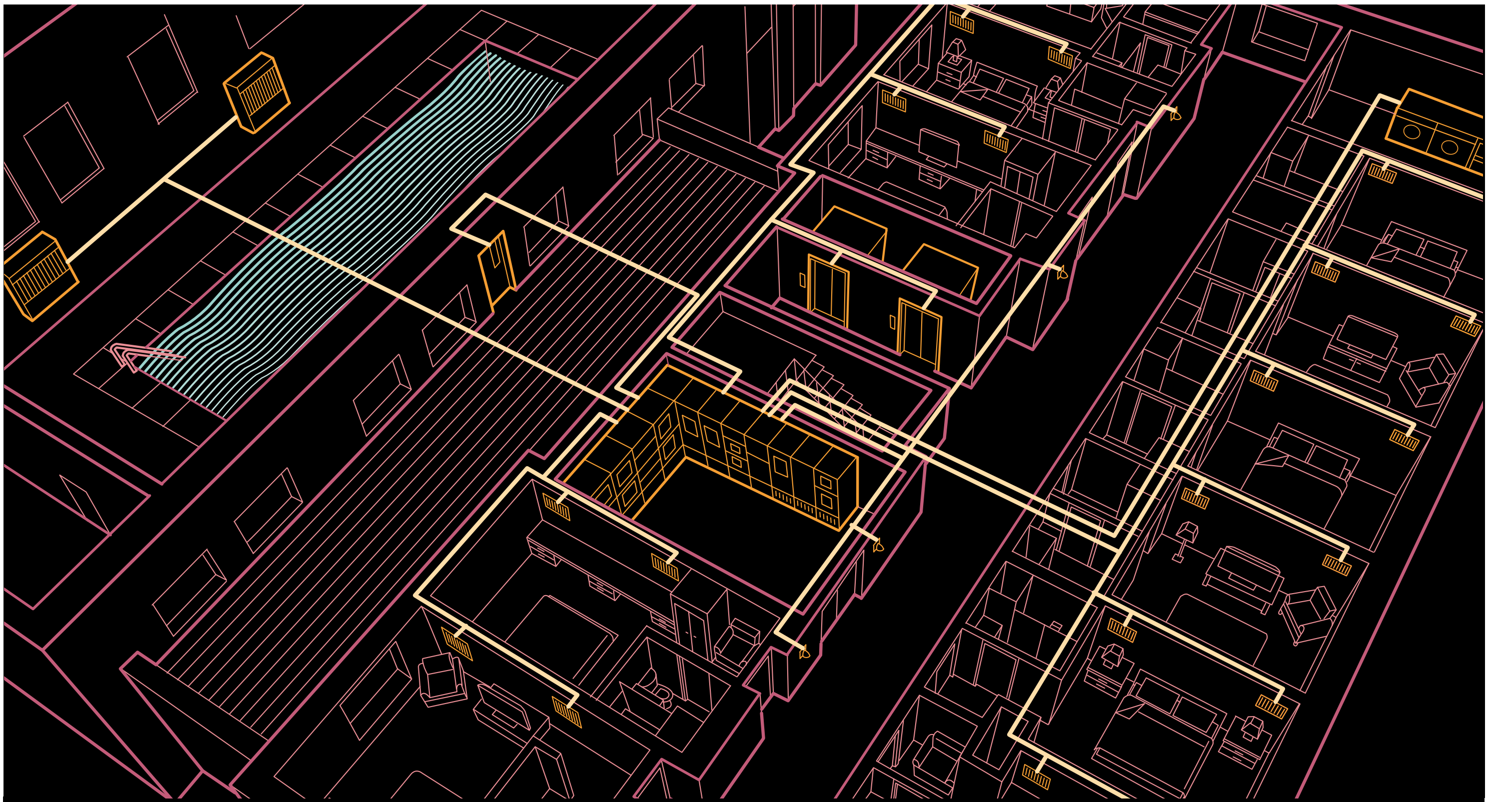


White paper

Load management with Ekip Power Controller for SACE Emax 2

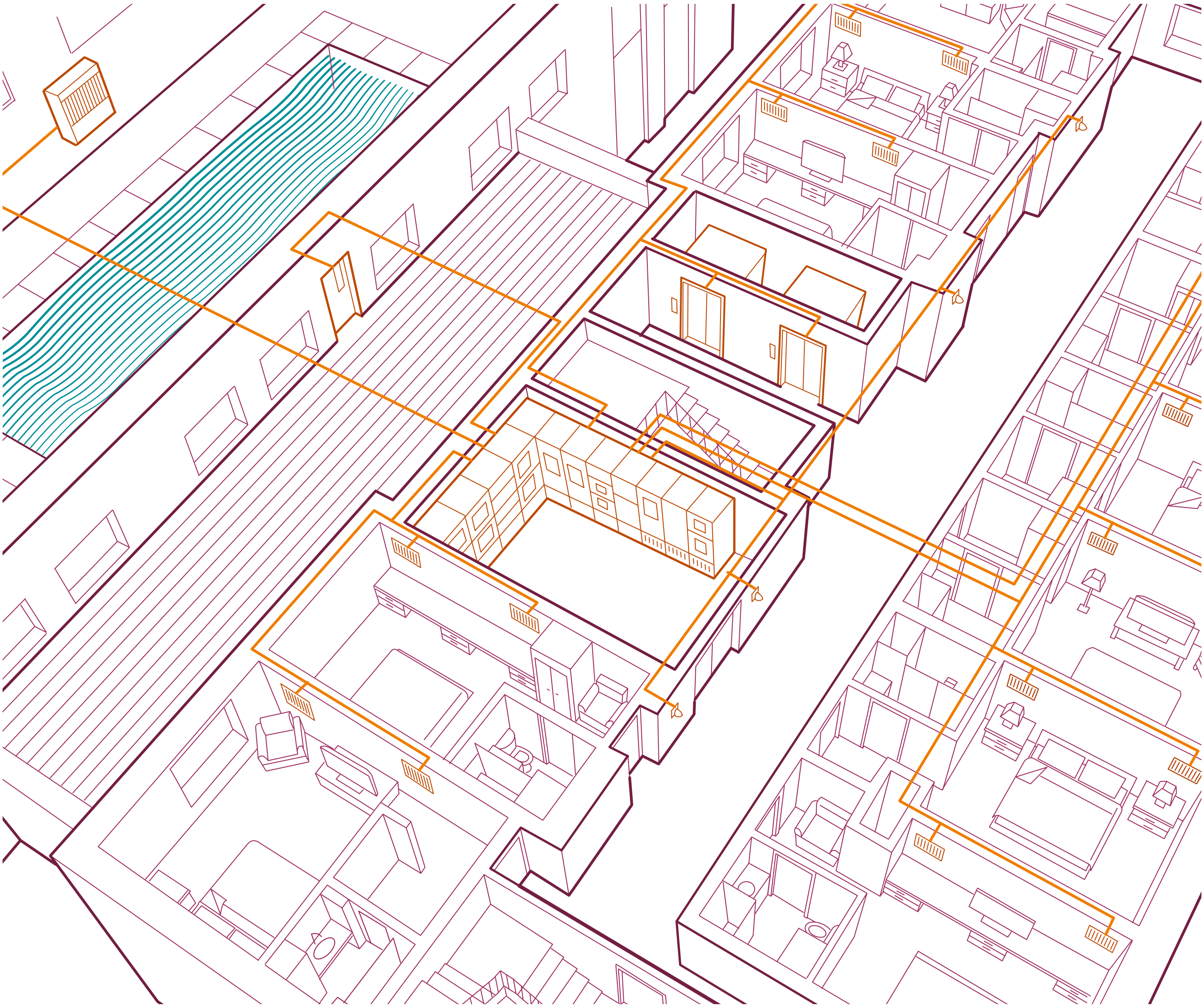
Power and productivity
for a better world™

Load management with Ekip Power Controller for SACE Emax 2

Index

Introduction

Nowadays careful consideration of electric power consumption represents a primary commitment, both in order to reduce the costs linked to consumption as well as for the issues linked to environmental sustainability.
An automatic control of the loads, based on the absorbed power, is an optimum solution for an effective cost reduction.
The target of these control systems is to modulate the demand for electric energy by avoiding a non-coordinated operation of the loads.
For example, during a hot summer day, air conditioners may start to work all at the same time, thus causing consumption peaks and consequent problems with energy supply.
In an effort to avoid exceeding energy usage contractual agreements with utility suppliers, plant managers may find themselves raising the initial limits; consequently increasing costs.
Furthermore, in the worst cases, plants may even have to be oversized in order to prevent overload tripping.
A system dedicated to the traditional control of loads may require the installation of a large number of dedicated control devices. The greater the number of loads to be controlled, the greater the complexity of electrical installation required to individually manage each load.
This can command a lofty initial investment when taking into account the complexity and the extra time required to design and ultimately complete the application.



1. Load management with Ekip Power Controller for SACE Emax 2

Ekip Power Controller, available for the new **ABB SACE** air circuit breakers type **SACE Emax 2**, is the ideal solution for load management and represents an optimum compromise between reliability, simplicity and cost-effectiveness.
This function is integrated in the electronic trip unit already used for the protection against overcurrents; as a consequence, neither complex control systems nor the implementation of dedicated software programs are necessary.
This function is based on a *patented* calculation algorithm that allows a load list to be controlled through the remote command of relevant switching device (circuit breaker, switch-disconnector, contactor…) or control circuit according to a priority defined by the User, based on his own requirements and types of load.
The algorithm is based on a foreseen average power absorption which can be set by the User over a determined time interval; whenever this value exceeds the contractual power, *Ekip Power Controller* function intervenes to bring it back within the limits.
This system can be realized with a single circuit breaker equipped with this function and installed as the main breaker of a low voltage plant. This one breaker can decide (according to the total energy absorbed from the grid and to the set parameters) when and which load to connect and disconnect.
Furthermore, the circuit breaker equipped with the function Ekip Power Controller, shall not only command the passive loads, but it can also command a reserve generator.
The remote command sent to the downstream devices can be performed in two different ways:

- through the wired solution, by commanding the shunt opening/closing releases or acting on the motor operators of the loads to be managed;
- through a dedicated communication system.

The ability to control the loads according to a list of priorities defined by the User provides significant advantages from both economic as well as technical points of view:

- economical: energy consumption optimization is focused on the control of the costs linked in particular to the penalties that are levied when the contractual power is exceeded or when the contractual power is increased by the Distribution System Operator (DSO) as a consequence of exceeding the limit repeatedly
- technical: the possibility of power absorption over the contractual limits for shorter periods and, as well as, the management and the control of the power consumption over long periods of time. Thus it is possible to reduce the likelihood of malfunctioning due to overloads, or worse, complete inefficiency of the entire plant due to tripping of the LV main circuit breaker.

The aim of this White Paper is to describe the main characteristics of the *Ekip Power Controller* function, give some indications about the settings and connections of the different components of the system and through an easy and user-friendly example to make the potentialities of this new function and its relevant benefits stand out.

2. Electricity billing

Electricity billing by the utilities is often comprised of a two-part tariff structure, whereby one part depends on the power demand (kVA or kW), while the other depends on the actual energy drawn (kWh) during the billing cycle.
Some utilities also record and bill the user for reactive energy as this also effects the load on the electrical lines.
Accordingly, utilities charge for maximum demand, active energy and reactive power drawn (as reflected by the power factor) in its billing structure. In addition, other fixed and variable expenses are levied.

The tariff structure generally includes the following components:

- *Maximum Demand Charges* - These charges relate to maximum power demand (kW) registered during month/billing period and corresponding rate of utility.
- *Energy Charges* - These charges relate to energy (kWh) consumed during month / billing period and corresponding rates. Some utilities now charge on the basis of apparent energy (kVAh), the vector sum of active (kWh) and reactive (kvarh) energy.
- *Power factor penalty or bonus rates*, levied by most utilities, relate to the reactive power drawn from grid.
- *Fuel cost adjustment charges* as levied by some utilities to take into account the increasing fuel expenses over a base reference value.
- *Electricity duty charges* levied with respect to units consumed.
- *Meter rentals*
- *Time Of Day (TOD)* rates like peak and non-peak hours are prevalent in the tariff structure provisions of some utilities.
- *Penalty* for exceeding contract demand
- *Surcharge* if metering is at LV side in some of the utilities.

Energy managers can analyze the utility billing data as well as monitor its trends to try and identify ways to reduce electrical bills (provisions in the tariff framework may make this possible) in addition to energy budgeting.

The utility employs an electromagnetic or electronic trivector meter for billing purposes.
The minimum outputs from the electromagnetic meters are:

- maximum demand (kVA or kW) registered during the month, which is measured in preset time intervals (e.g. 15 or 30-minute duration) and this is reset at the end of every billing cycle
- active energy in kWh during the billing cycle
- reactive energy in kVArh during the billing cycle
- apparent energy in kVAh during the billing cycle.

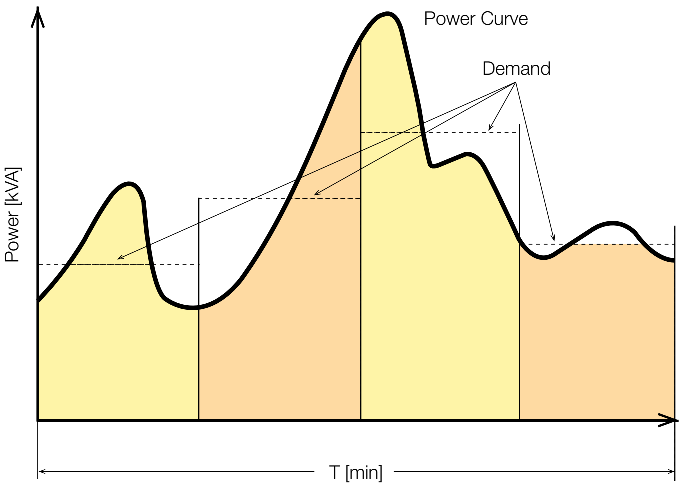
It is important to note that the maximum demand recorded is not the instantaneous demand drawn, but the average value of power obtained by the ratio between the energy absorbed during the predefined time interval and the time interval itself.

For example, in an industrial plant, if the total power drawn over a recorded cycle T (in this case 30 minutes) varies as follows:
2500 kVA for 4 minutes
3600 kVA for 12 minutes
4100 kVA for 6 minutes
3800 kVA for 8 minutes
the maximum demand recorded will be calculated as:

$$\frac{(2500 \cdot 4)+(3600 \cdot 12)+(4100 \cdot 6)+(3800.8)}{30} = 3607 \text{ kVA}$$

The diagram in Figure 1 illustrates the average power consumed in four different time intervals over a 30-minute period (see the above formula).
The dashed straight lines show the average power consumption, whereas the continuous curved line shows the actual power consumption.

Figure 1



The month's maximum demand will be the highest among the demand values recorded over the month.
The *smart meter* registers only if the value exceeds the previous maximum demand value. Thus, although the monthly average demand may be low, the user shall have to pay the maximum demand charges for the highest value registered during the month, even if it has occurred for just one recording cycle duration (e.g. 30 minutes).
In an electrical system macro perspective, the growth in the demand for electricity by the more and more diverse end user segments along with the timing of their use, has led shortfalls in capacity to meet demand.

As a solution, the construction of new generation power plants, to help keep up with energy demands, can prove to be costly as well as a long wait prospective. Better load management on the side of the user can help to minimize peak demands on the utility infrastructures as well as to improve the utilization of power plant capacities.

The utilities or electricity distribution companies can use power tariff structures to influence end user consumption utilizing measures such as: time of use tariffs, penalties on exceeding allowed maximum demand, correct demand, night tariffs, and concessions.

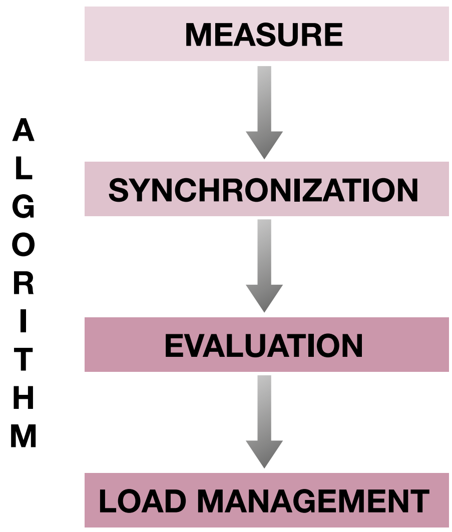
Load management is a powerful means of efficiency improvement both for end Users as well as for utility companies.
It is important to keep in mind (from a user's perspective) that since demand charges constitute a considerable portion of the electricity bill, there is a real need for integrated load management to effectively control the maximum demand in the billing cycle.

3. Description of operation

Ekip Power Controller is a real time advanced control system whose main purpose is to limit the average the average power consumption in each defined time interval to a pre-determined maximum value (contractual power). This result is obtained by disconnecting simultaneously some loads (which are considered by the User non-priority loads) when the patented implemented algorithm considers it necessary. These loads are then reconnected when the algorithm deems that the average power demand identified by the utility contract is no longer exceeded. The Ekip Power Controller algorithm perpetually works to optimize the number of loads connected by constantly trying to supply as large a section of the plant as possible. *Ekip Power Controller* chooses the loads to be disconnected according to the priority defined by the User.
The identification of the loads to be managed and to what extent (how often and how long) is a fundamental action to be carried out in advance in each load management program.
Among the types of loads that can be managed there are:
- *thermal and refrigerating loads* – such loads can usually work in a certain temperature range and can tolerate some deviations from the optimum value. This makes it possible to reduce or increase the energy consumption whenever necessary, with limited impact on the performances. Another characteristic of this type of loads is their storing capacity, which grants a further flexibility when the working cycle varies, without altering the process. Examples of thermal electric users are furnaces and ovens (induction, resistance, arc type, etc.), water heaters, stoves, refrigerators, freezers and air conditioners
- *lighting apparatus* – it is possible to reduce the light flow of a group of lamps and maintaining at the same time the minimum lighting defined in the design phase (e.g. groups of lamps for outdoor environments or garages)
- *delayed start loads* – in some installations the starting up of the motors connected to pumps for particular fluids can be deferred in the short time (e.g. storage air compressors for production cycles or swimming pool circulation pumps)
- *charging systems for electric vehicles* – recharging of electric vehicles can be managed by modulating the power absorbed by the batteries over short periods
- *generators* – diesel/electrical generators or generators connected to renewable sources can be inserted in the event of a particular energy demand; such generators can be considered from the point of view of *Ekip Power Controller* as loads with negative power.

The algorithm of *Ekip Power Controller* consists of four steps (Figure 2):

Figure 2



1. *Measure*: it measures the total power flow through the circuit breaker SACE Emax 2 which implements the function. Afterwards, this value is integrated to obtain the total energy. When each reference time interval has elapsed, the energy is set to zero. In such way, the evaluation modulus of the algorithm has always at its disposal the value of the energy measured in the current interval of time.
2. *Synchronization*: based on the clock inside the trip unit, the algorithm defines the time intervals in which the average power demand is measured (a typical value in is 15 minutes) . During each reference period, at regular intervals (e.g. every minute), it starts the evaluation module. As an option, it can be synchronized by an external signal given by the smart meter of the DSO.
3. *Evaluation*: based on the energy measured and on the time elapsed from the beginning of the reference period, the algorithm evaluates whether the demand is too high (that is if the average power limits are likely to be exceeded in that period), whether it is within the normal limits or whether it is significantly lower. On the basis of these cases, one of the three following results is generated:
   - if the absorbed energy is within the limits, the decision is to keep the existing load configuration (number of connected loads)
   - if the absorbed energy is too much, the decision is to decrease the existing load configuration
   - if the absorbed energy is remarkably lower, the decision is to increase the existing load configuration.

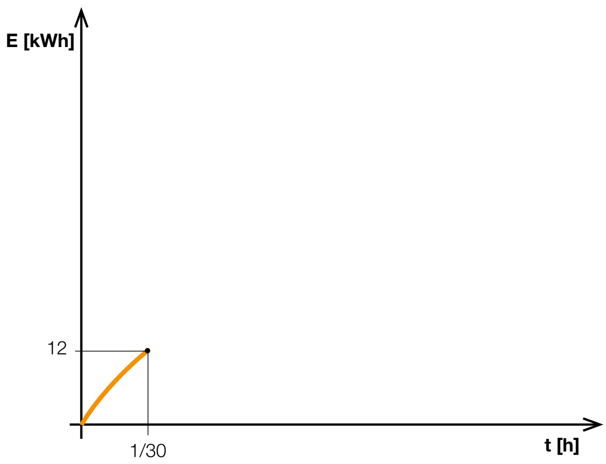
[1] If a device is available to signal the tariff time bands, *Ekip Power Controller* can use it to synchronize its clock.

4. *Load management*: based on the decision resulting from the evaluation module, the system decides which loads are to be disconnected or reconnected, in compliance with the following rules:

- *priority* – if it is necessary to disconnect a load, and when more than one load can be chosen for this operation, the indication and the order given by the User in the list of the controllable loads is followed: the first load on the list is typically the least important for the application or that which can be temporarily disconnected. The second load immediately follows for importance and so on. Likewise, when a load must be reconnected, the algorithm follows the set list in the reverse order (starting from the last load in the list), that is starting with the reconnection of the load with the utmost priority for the plant. The algorithm complies with the priority order set by the User, in compliance with the respected time mentioned below. It also considers when a breaker is open due to a trip, or if it has been purposely opened by the user (e.g. maintenance or shut down).
- *respect times* – every load may have minimum times in which it must remain connected (or disconnected) to avoid damage. Therefore, when choosing the load to be connected or disconnected, the algorithm will not consider any load that has just been switched. When this is the case it jumps to the following load on the list.
- *reordering* – when a load becomes available again because its respect time is over, it is connected or disconnected according to its position in the list.

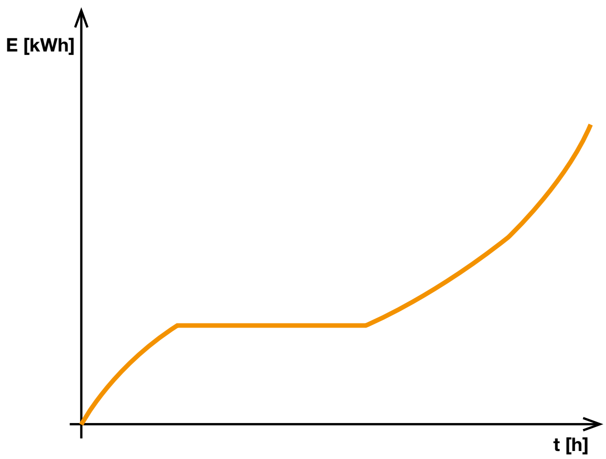
It is possible to set the same priority for two or more loads: this means that they are of the same importance for the plant and therefore it is not necessary to define which one has to be disconnected first. In such case, *Ekip Power Controller* shall disconnect one or more of these loads, switching the load which has not been operated for the longest period of time first. In occurrences when more than one load of the same priority level is to be disconnected, the controller simply switches them in order.
The core of *Ekip Power Controller* is the evaluation module. It operates based on the energy demand with reference to the time elapsed from the beginning of the set reference period. By considering the two variables time t (h) and energy E (kWh) respectively, the time elapsed from the beginning of the period and the energy withdrawn by the plant in that interval, it is possible to represent the actual state of the electrical installation through a point in the plane t,E.
For example, if two minutes (1/30 h) have elapsed and the energy demand has been 12kWh, the point is represented in Figure 3.

Figure 3



As time passes, the point describing the state of the system moves towards higher values of t. Energy E is increasing or however it can remain constant if the energy consumption is null. Then, the total energy absorption is described by the curve of Figure 4.

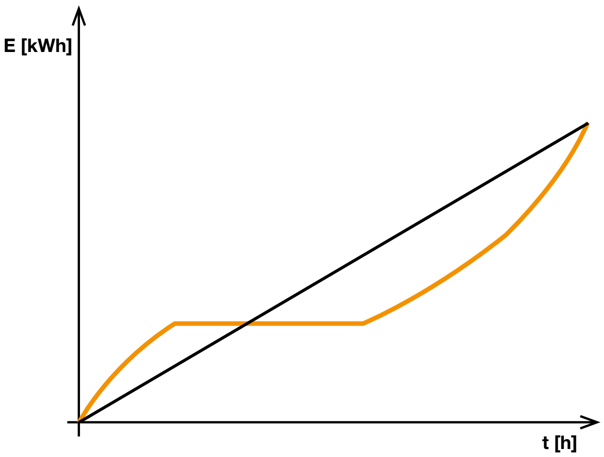
Figure 4



The same total value of energy can be obtained with very different trends; if, for example, the power value is constant, a line going through the origin of the axes is obtained.
But the same value can be obtained also with a low con-

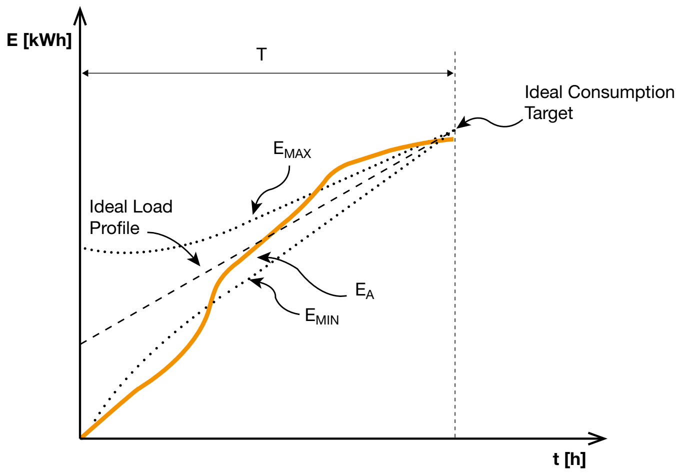
sumption for a certain period, followed by a high consumption for a few minutes (Figure 5).

Figure 5



Since *Ekip Power Controller* is aimed at keeping the total value of energy in the reference period below the set limit, the software examines the trend of the curve up to the current moment and evaluates the energy consumption at the end of the period, verifying that the ratio between such consumption and the predefined period does not exceed the contractual power limit. If this limit is exceeded, the disconnection of one or more loads is commanded.
Practically the evaluation phase divides the plane t,E in three zones, indicative of acceptable consumption, high consumption and reduced consumption.
Whenever the evaluation phase is processed, the software finds the point that describes the current situation and determines to which of the three zones it corresponds. If the point falls in the high consumption area, the result of the evaluation indicates that it is necessary to disconnect one of the loads and such evaluation is transmitted to the load management module that chooses which one. The operation described is performed at regular intervals, every time calculating a new forecast. In this way, if the forecast of the total power absorbed by the plant is still too high in spite of the disconnection of one load, the algorithm proceeds to disconnect another load and so on. Then the number of the controlled loads disconnected and connected varies dynamically, with the aim of making the power forecast coincide with the target value.
To describe it, the algorithm tends to "guide" the energy-time line which represents the energy absorption by the plant as this line develops from zero (at the initial instant of the reference period) up to the arrival point (the final instant of the period), trying to keep it always within a predefined intermediate zone (bounded by two curves calculated by the algorithm) by disconnecting the loads when the line enters the upper zone or by reconnecting them when the line passes into the lower one (Figure 6).

Figure 6



In Figure 6, the thick line (orange) shows the total energy actually consumed E_A by the plant starting from time t=0.
The disconnection of a load causes a decrease in the slope of the curve, whereas the reconnection has the opposite effect. As can be seen, the curve never decreases as time passes (it would be a horizontal line if there were no power consumption). The dotted lines (E_{MIN}, E_{MAX}) represent the boundaries between the three regions: whenever the curve crosses one of such boundaries, the algorithm reacts with load connection or disconnection.
The three zones are not separated by straight lines, but by curves: these are polynomial curves optimized by the software according to the number of loads and so as to permit the consumed power to exceed the maximum allowed level (also significantly), provided that the total energy consumed in the period does not risk to exceed the limit (having the average value of the power lower than the contractual limit).
Therefore if, at a given instant, the power is very high, but for a short period only, *Ekip Power Controller* shall not trip. If in-

[2] The most important measure on which *Ekip Power Controller* is based is the instantaneous power flowing through the circuit breaker on which it is implemented. The instantaneous power is continuously measured and integrated during the time to obtain the measure of the energy.

stead the power demand is high for a long time, one or more loads shall be disconnected. Likewise, if the consumption has been very low in the initial part of the period, it will be possible to use a higher power in the final part without provoking a disconnection. Thus it is evident that a remarkable advantage of this algorithm is its flexibility as regards the use of power, which is reduced only if necessary, that is when the average limit set by the User is near to be exceeded.

The main advantages of *Ekip Power Controller* are:

- control of up to 15 loads and/or generators through a single circuit breaker SACE Emax 2
- easy implementation since each load/generator is controlled by means of a circuit breaker, switch-disconnector, contactor or its own control circuit
- easy operation since just few simple parameters must be set on the Ekip trip unit of SACE Emax 2
- compatibility with any type of load/generator thanks to the possibility of setting tailored working/not working times for each of them
- writing of programs for programmable logic controllers (PLCs) or computers (PCs) is not required since the software for the application is already implemented in Ekip trip units. Besides, the solutions based on the use of PLCs or PCs are characterized by high costs and high complexity, thus justifying its use when dozens of loads must be controlled and/or when a complete supervision of the plant is necessary
- management/control of the power absorption exceeding the defined limit for long periods of time result in the consequent reduction of the likelihood of malfunctions due to overloads and stress on the components of the electrical plant
- thanks to the function modes of the algorithm, *Ekip Power Controller* is less sensitive to brief absorption of high power (e.g. motor start-up transients or time-limited simultaneous operation of more loads) in comparison with the systems that use only the instantaneous power as a parameter. In fact these type systems needlessly disconnect loads as soon as the power exceeds the set threshold limit. This reaction can be premature and can often results in an under utilized energy quota available for a given period.
- thanks to the feedback system on the measurements of consumed power, it is not necessary to know detailed data of each load (time-power curves, etc.).
  Nor is the measure of the power in real time for each controlled load necessary, since the measure of the total power absorbed by the plant is enough. In other words, it is not necessary to know whether a load in the priority list is or is not absorbing power and how much: knowledge of the state "open/closed" of the related switching device is enough. In other words, it is not necessary to know whether a load in the priority list is or not absorbing power and how much: knowledge of the "open/closed" state of the related switching device is enough. In fact, by sampling the total energy absorbed at given intervals, the algorithm disconnects a further load if it does not find a reduction as a consequence of the last disconnection carried out: thus, the number of disconnected/connected loads varies dynamically so that only the minimum number of loads is disconnected not to exceed the contractual power limit
- reconnection of the loads is intelligently managed: not simultaneous but load by load, that is whenever an evaluation phase is carried out; in such way, inrush current peaks, which could cause voltage perturbations in the plant and make the short-circuit protections trip, are avoided
- adaptation of the energy demand to the availability of the preferred energy source, to the energy cost and to the time of the day (management through up to four different time bands) so that costs can be optimized and emissions reduced
- thanks to a reduction in the average absorbed power, in the designing phase it could be possible to reduce the size of the MV/LV transformer and the cross-sectional area of the LV connection cable between the secondary of the transformer and the main circuit breaker, thus also reducing the rated current of the circuit breaker
- thanks to the reduction in the average absorbed power, it is also possible to reduce the fixed costs (power quota) for the electrical energy dispatch/distribution service
- leveling of the daily load curve, by limiting the consumption during the day when the tariffs of the electrical energy are higher and by favoring higher energy demand in the night, contributes to a better efficiency of the whole electrical system when considering it from a Smart Grid point of view. Thus, there is a reduction in the likelihood of overloads on electrical lines, which could result in a non-optimum redistribution of the total production, and limits the use of the "peak" power stations which have low efficiency and high service costs.

Furthermore, the algorithm of *Ekip Power Controller* is able to manage automatically also the following situations thus allowing the integration with the selectivity of the protection

3. Description of operation

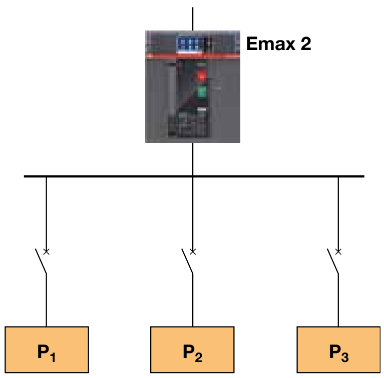
devices installed in the plant:

- *tripping of protection trip units* - if one of the controlled circuit breakers opens due to a protection trip, for safety reasons (in particular not to reclose on a short-circuit) it can no longer be managed by the controller as it will be deemed "not available for control" by the algorithm. It will remain in this state until the user has reset the breaker and made it available again. More specifically, if a controlled circuit breaker is tripped due to the overcurrent release, the algorithm, after three attempts to issue an opening command, gives an alarm signal and temporarily excludes that circuit breaker from the priority list until the trip state has been reset: the reset operation can be carried out through local manual command from display or through Ekip Connect remotely.
- *manual operation* – the loads are considered “not available” also when the operator acts manually on the relevant circuit breakers. Such loads will remain in that condition until reactivation is commanded by the operator.

3.1 Example of operating logic

Supposing we have an electrical plant (Figure 7) which consists of three big loads, one priority load (P_3) and two non-priority ones (P_1 and P_2). P_1 and P_2 can be managed through the *Ekip Power Controller* logic in compliance with the principle described below. In this example, the time interval of action of the algorithm is set by the User to 15 minutes.

Figure 7



At the moment the synchronization signal is sent from the DSO meter, the three loads are all connected with a total power lower than the limit contractual power (P_c =1500 kW). With reference to the diagrams of Figures 8 to 11, at the instant t1 there is a peak of power absorption of load P_3, but its duration does not exceed the set limit for power demand in 15 minutes ($E_a = P_c$*0.4 [kWh]) according to the evaluation of *Ekip Power Controller* algorithm. As a consequence, none of the non-priority loads is disconnected.

At the instant t_2 the power absorption of P_3 increases so that the sum of the three power demands exceeds the contractual power and with such duration that the result of the algorithm forecast is a value exceeding the absorbable energy. As a consequence, *Ekip Power Controller* disconnects the load P_1, which comes before P_2 in the priority list for disconnection. The load P_2 must stay disconnected for a minimum time t_{1min_off} (i.e. up to the instant t_4). This minimum time is necessary to avoid too frequent switching operations which can affect life of the switching devices and proper load operation.

At t_3 the power absorption of P_2 increases, but since the sum of P_2 and P_3 is lower than the contractual power P_c the algorithm does not intervene.

At t_4 *Ekip Power Controller* consents to reclose P_1, also because the load P_3 has reduced the absorbed power and therefore the total absorption of the three loads is lower than P_c.

At t_5 there is a further increase in the power absorbed by P_3 such that the sum of P_3 and P_2 is already higher than the contractual one and the duration is such that *Ekip Power Controller* detects the risk of exceeding the absorbable energy.

As a consequence, the algorithm disconnects firstly the load P_1 in t_6 (in compliance with the minimum time t_{1min_on}), but by evaluating the possibility of exceeding the absorbable energy, in t_7 it disconnects also P_2.

After the minimum times t_{1min_off} and t_{2min_off} of P_1 and P_2 respectively, since the power absorbed by P_3 has decreased, the algorithm reconnects the loads according to their connection priority (times t_{1min_off} and t_{2min_off} permitting) and the operation logic repeats indefinitely for each time interval defined by the User.

As can be noticed in the diagram which represents the total load (Figure 11), in the considered interval of 15 minutes there can be some power absorptions exceeding the contractual power limit P_c, but, thanks to the algorithm of *Ekip Power Controller*, the average power P_m absorbed always remains under the limit contractual power P_c.

Figure 8 - Load P_1

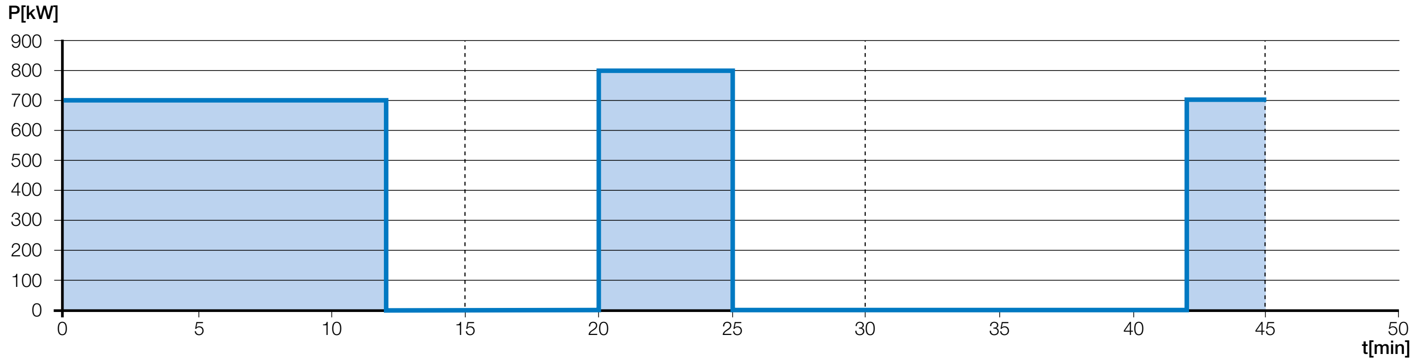


Figure 9 - Load P_2

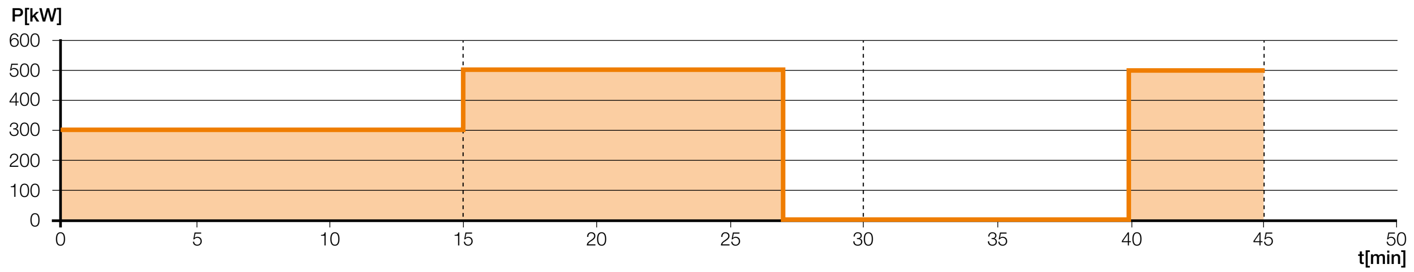


Figure 10 - Load P_3

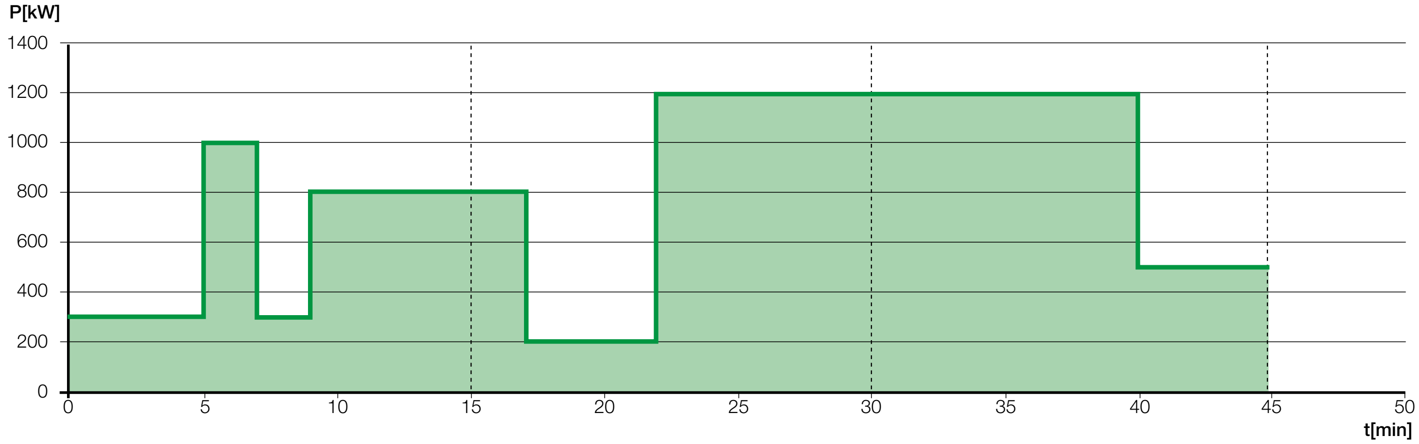
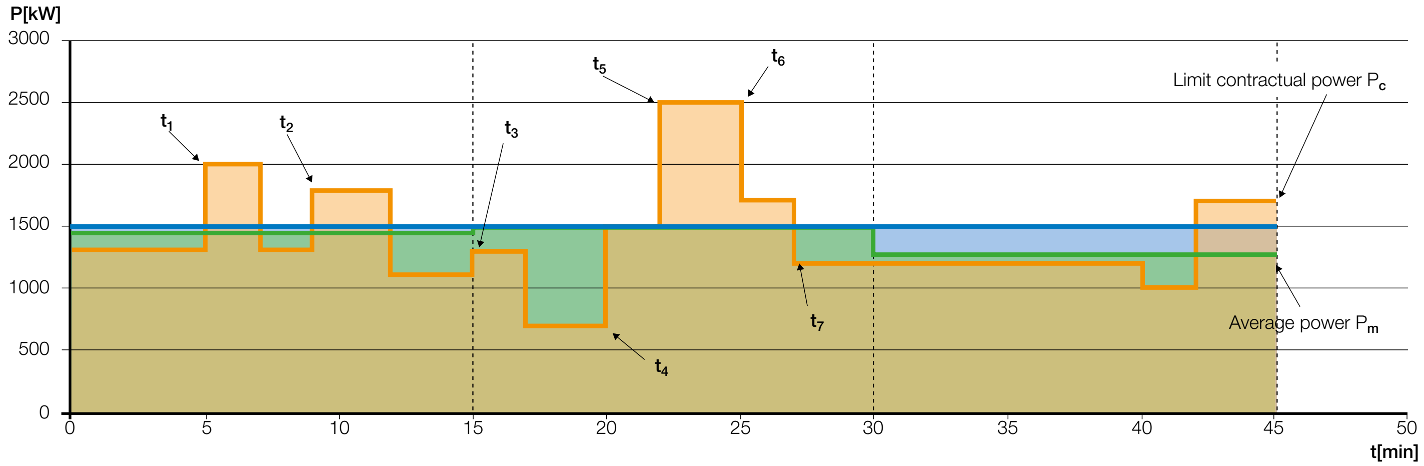


Figure 11 - Total load



4. Settings and connections

Physically, *Ekip Power Controller* systems consist fundamentally of:

- an air circuit breaker type SACE Emax 2 with protection trip unit (*Ekip Hi Touch* or *Ekip Touch* + *Ekip Measuring*) operating as power controller and meter. Such a circuit breaker, installed as main LV breaker, implements the algorithm of *Ekip Power Controller* which manages the load connection and disconnection
- a variable number (from 1 to 15) of controlled LV apparatuses (circuit breakers, switch-disconnectors or contactors), each of them installed on the supply circuit of one of the loads subject to control.

Each load/generator is controlled in one of the following ways:

1. wired control, through shunt opening/closing releases (YO / YC) or motor operator and applicable to any circuit breaker (moulded, air or miniature circuit breakers), switch-disconnector, contactor or through the control/start circuit
2. Ekip Link control, through Ethernet cable and applicable to any circuit breaker or switch-disconnector of the new series SACE Emax 2 equipped with Ekip Link module.

A main circuit breaker SACE Emax 2 equipped with Ekip Power Controller uses the following input/output digital signals for every wired-controlled load:

- 1 digital input (mandatory) to get information about the open/closed state of the downstream device
- 1 digital input (optional) to get information about the enabled/disabled state of the downstream device (or tripped state or redundant contact of state)
- 1 digital output to give the opening/closing command to the downstream device when it is a contactor or a control circuit
- 2 digital outputs to give the opening/closing command to the downstream device when it is a circuit breaker or a switch-disconnector.

A digital input can be optionally used by SACE Emax 2 for time synchronization with the smart meter of the DSO.
The User must set a list of parameters for SACE Emax 2 circuit breaker equipped with *Ekip Power Controller* function. Such parameters are the following:

- *enable/disable* – enabling or disabling *Ekip Power Controller* function
- *power limits* – showing which is the average power (Pm) absorption not to be exceeded; setting this value is mandatory, whereas the others are optional and are needed to differentiate the power consumed in the various daily tariff bands
- *week scheduling* – indicating the four tariff bands in which week days (Monday to Friday) are divided
- *Saturday scheduling* – indicating the four tariff bands in which Saturday is divided
- *Sunday scheduling* – indicating the four tariff bands in which Sunday is divided
- *synch configuration* – indicating the presence and the reception channel for the synchronization signal of the smart meter
- *start-up behavior* – indicating which loads must be inserted in the list of the loads that can be managed at startup.

For each switching device that supplies a load to be managed, the following parameters must be set through Ekip Connect:

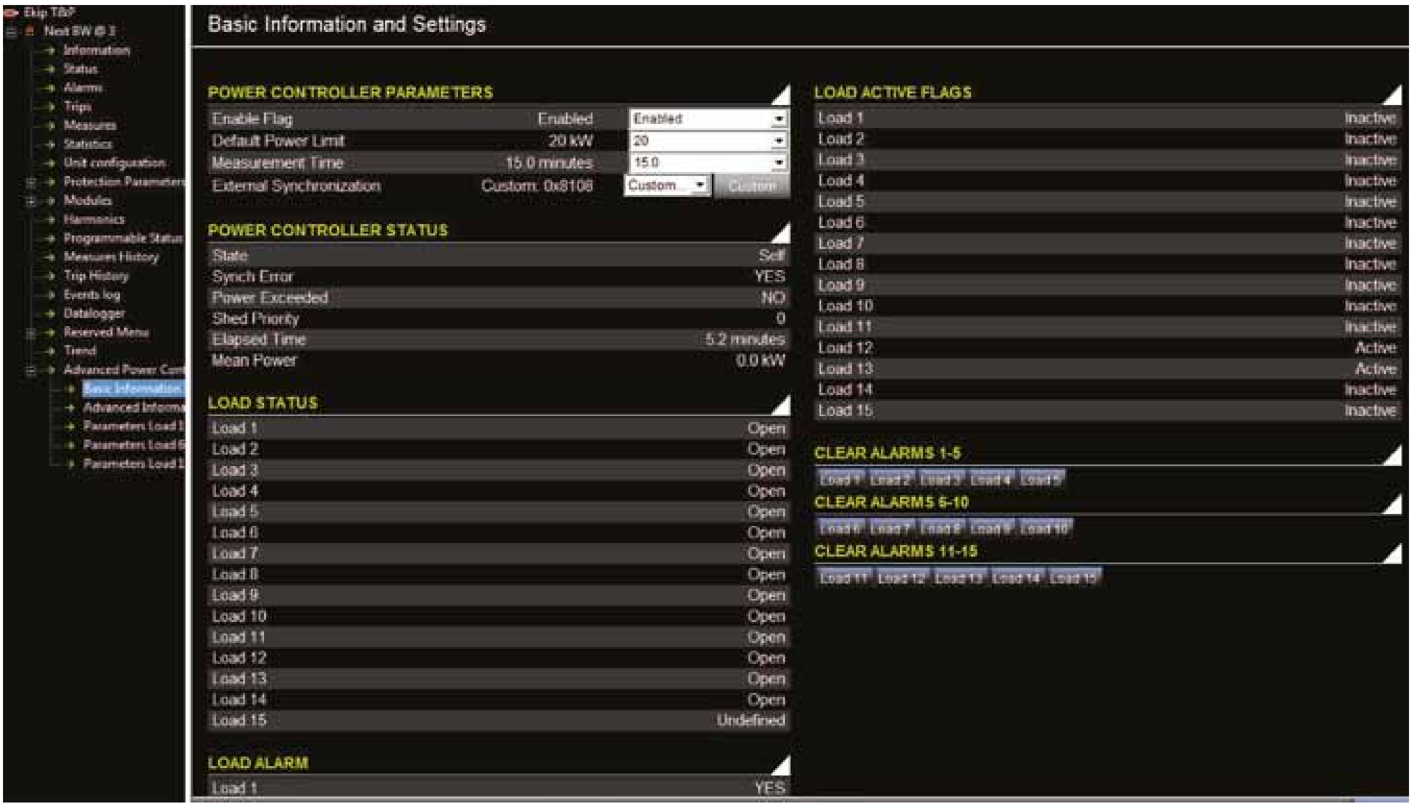
- *connection type* - selecting the number of input for each load
- *open/closed input* – indicating to which contacts (either Ekip Signalling or Ekip Link) the inputs for the open/closed state of the switching device are connected
- *optional input* – indicating to which contacts (either Ekip Signalling or Ekip Link) the auxiliary input is connected
- *enable/disable* – allowing load control to be disabled through *Ekip Power Controller* when the User does not wish that a given load is controlled by the algorithm for a certain time period. In such case, the algorithm by-passes that load and jumps to the following one in the priority list. For example this parameter can be useful when a load is undergoing maintenance
- *shed priority* – defining the priority with which the related load must be managed; it is represented by a number from 1 to 15 with decreasing priority of disconnection. There may also be more loads with the same priority: in that event, the algorithm proceeds to disconnect them alternately
- t_{on_min} – minimum time during which the load/generator must remain connected in order to protect it against too frequent start/stop operations; it is possible to set a null time or a time in the range from 1 to 360 minutes with 1-minute step
- t_{off_min} – minimum time during which the load/generator must remain disconnected in order to protect it against too frequent start/stop operations (e.g. gas-discharge lamps which need a minimum time to elapse between each switching-on operations); it is possible to set a null time or a time in the range from 1 to 360 minutes with 1-minute step
- t_{off_max} – maximum time during which the load can remain

disconnected in order to protect the process managed (e.g. cold rooms, electric ovens) against the damages caused by a prolonged lack of supply; it is possible to set a null time or a time in the range from 1 to 360 minutes with 1-minute step

- *time window* – time window in the space of the day during which the load cannot be disconnected; for example, this can be useful when there is a generator that can be started up and kept working in the daytime only to avoid noise pollution in the nighttime; it is possible to set a time interval from 1 to 24 hours with 1-hour step
- *user type* – type of user (load/generator)
- *nickname* – a string of 8 digits identifying the user.

The following figures show as an example some graphic displays of Ekip Connect: the window in Figures 12A-B shows the basic parameters that the User must enter for the main circuit breaker with *Ekip Power Controller*, Figure 13 shows the advanced parameters, whereas Figure 14 presents the window with the parameters to be set for each switching device of the load to be controlled.

Figure 12A – Basic information and settings



4. Settings and connections

Figure 12B - Basic information and settings

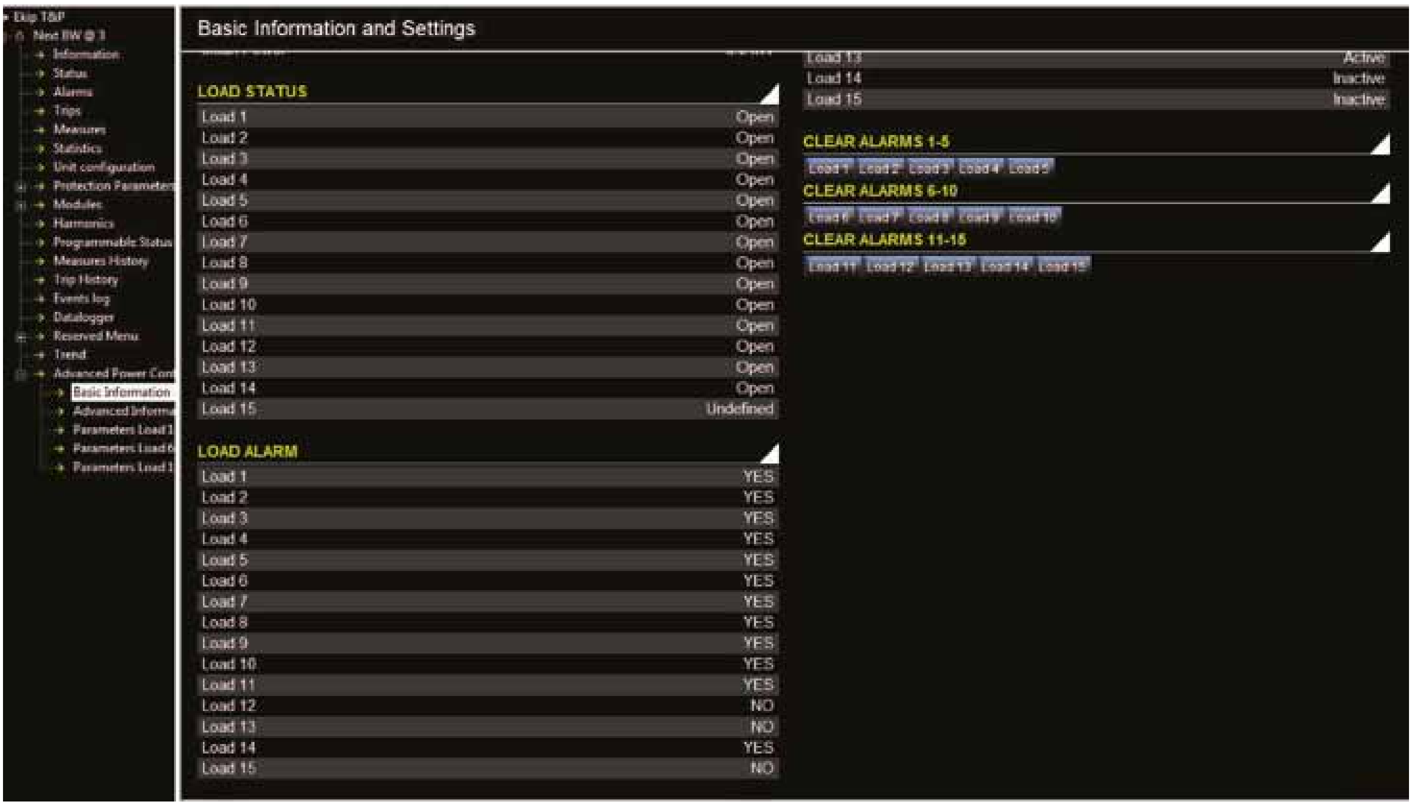


Figure 13- Advanced information and settings

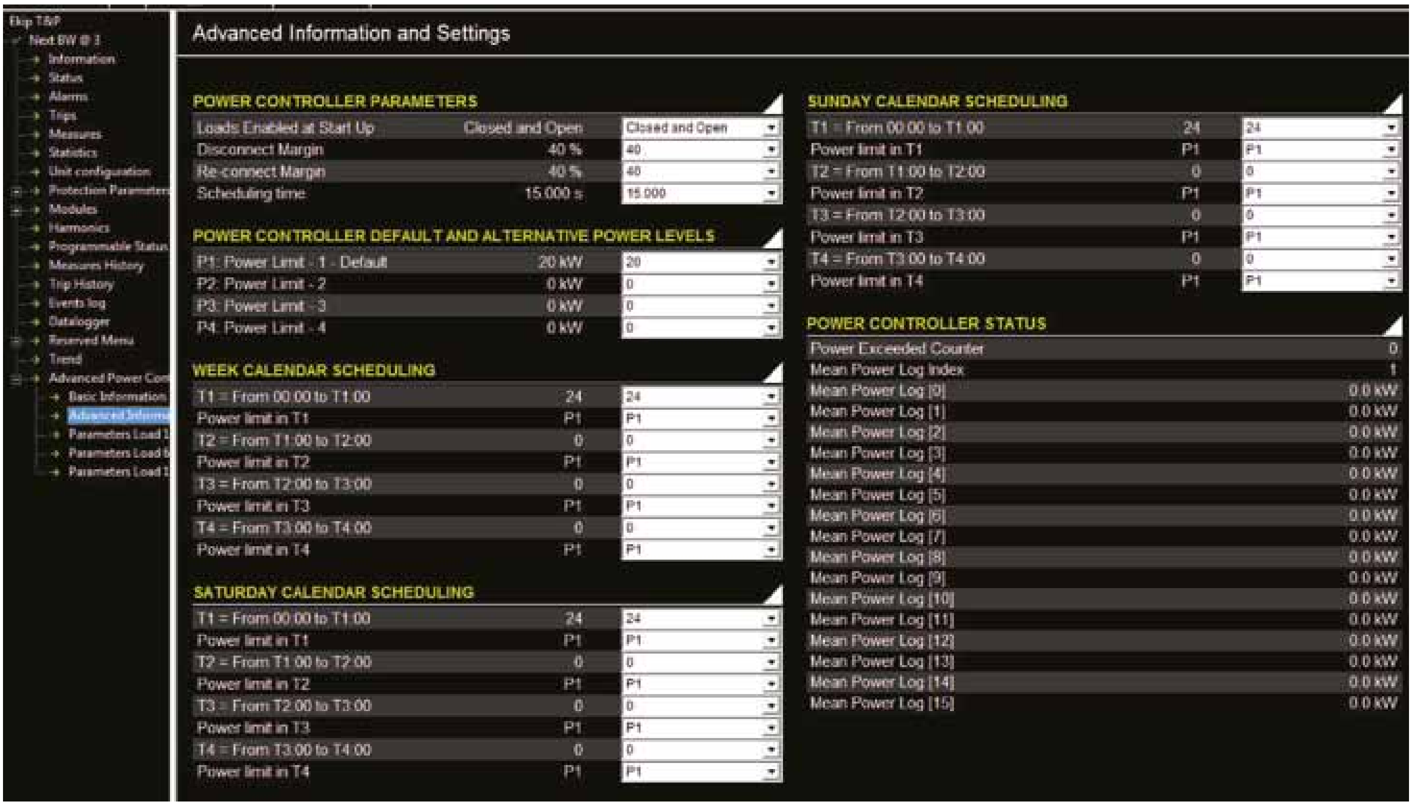
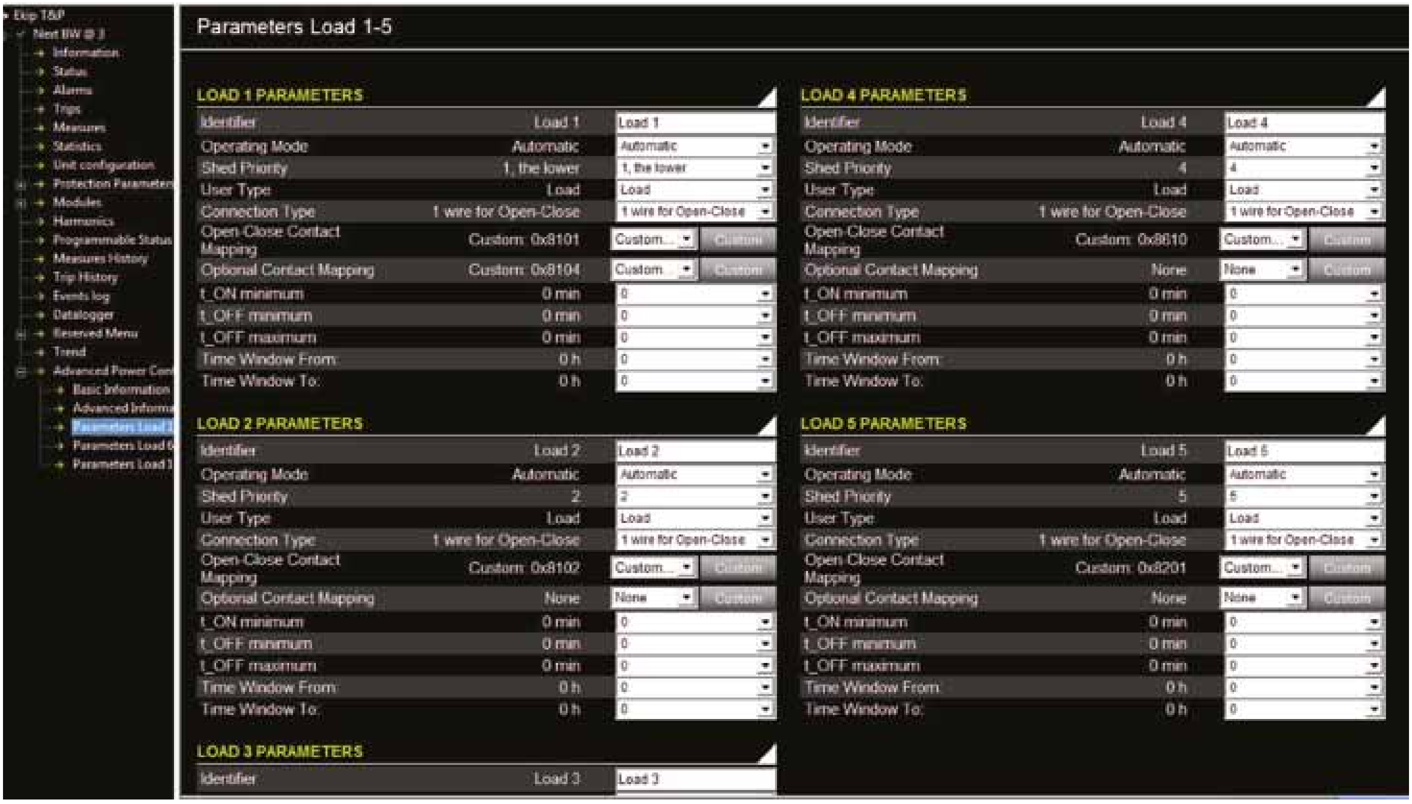


Figure 14 - Load parameters



4. Settings and connections

The typical scenarios for the connection between the main circuit breaker SACE Emax 2 equipped with *Ekip Power Controller* and other air/moulded-case circuit breakers or switch-disconnectors on the load side are given below, for installation both in the same switchboard and in different switchboards. However, as previously mentioned, there is the possibility to command contactors and control circuits too.

4.1 Scenario A: same switchboard

4.1.1 Scenario A1 – wired connections, controlled loads ≤ 5

With the circuit breakers SACE Emax 2.2 or 4.2 or 6.2 equipped with *Ekip Power Controller* it is possible to command up to five circuit breakers on the load side through Ekip Signalling modules (Figure 14). Instead, when using an Emax 1.2 outfitted with an Ekip Power Controller, two downstream circuit breakers can be controlled through wired connection.

The main circuit breaker SACE Emax 2 must be equipped with:

- *Ekip Power Controller* function (with Ekip Measuring Pro if the trip unit is not Hi Touch)
- Ekip Supply module
- Ekip Signalling modules
- for each controlled load/generator:
    - 1 digital input for the open/closed state of the switching device
    - 1 digital input to enable/disable the switching device (optional)
    - 1 digital output to give the opening/closing command to the downstream device in case it is a contactor or a control circuit (in latched mode)
    - 2 digital outputs to give the opening/closing command to the downstream device in case it is a circuit breaker or a switch-disconnector (in not latched mode)
    - 1 digital input for clock tick synchronization with the smart meter of the DSO (optional).

Each controlled air circuit breaker or switch-disconnector type SACE Emax 2 must be equipped with the following accessories[3]:

- shunt opening release (YO)
- shunt closing release (YC)
- geared motor for automatic charging of the closing springs (M)
- contact for electrical signalling of open circuit breaker due to overcurrent release tripped (S51), not available in case of switch-disconnector
- circuit breaker open/closed auxiliary contact (Q/1).

Each controlled moulded-case circuit breaker type Tmax and SACE Tmax XT must be equipped with the following accessorie[3]:

- stored energy motor operator (MOE) or direct action motor operator (MOD)
- contact for electrical signalling of open circuit breaker due to overcurrent release tripped (S51), not available in case of switch-disconnector
- circuit breaker open/closed auxiliary contact (Q/1).

Each controlled miniature circuit breaker type S800, S200 and DS200 must be equipped with the following accessories[4]:

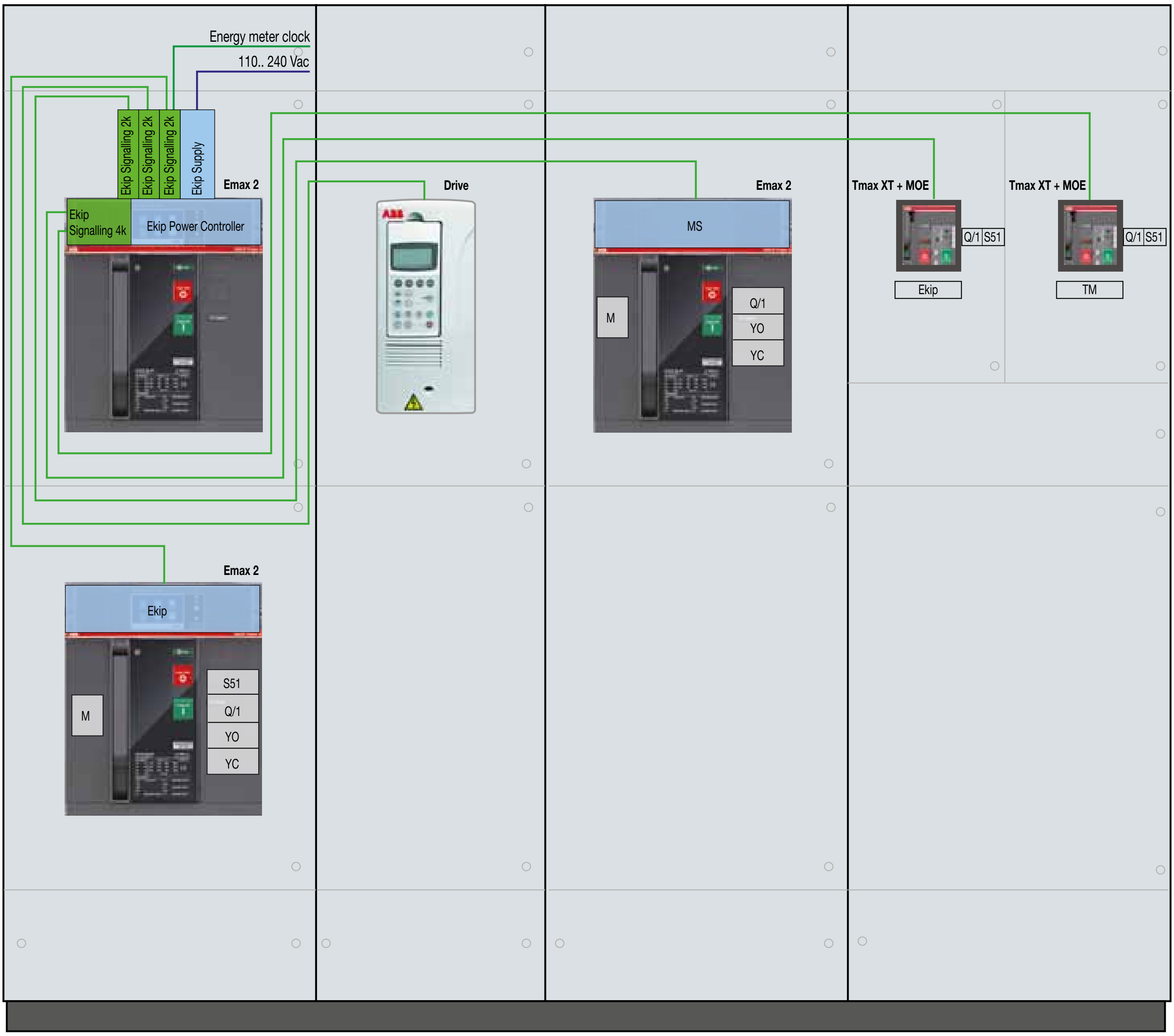
- S800-RSU-H motor operator for thermal magnetic circuit breaker S800 series
- S2C-CM motor operating device for thermal magnetic circuit breakers S200 series and DS2C-CM for thermal magnetic residual current circuit breakers DS200 series.

---

[3] It should be reminded that a connection must be provided to an auxiliary voltage (110... 240Vac) for the supply of the shunt opening/closing releases, of the motor for spring charging and of motor operators type MOE and MOD.

[4] It should be reminded that a connection must be provided to an auxiliary voltage (see the catalogue "System pro *M* Compact") for the supply of motor operators and motor operating devices. The contacts for signaling of open/closed circuit breaker and open circuit breaker due to overcurrent release tripped are integrated in the motor operator and in the motor operating device.

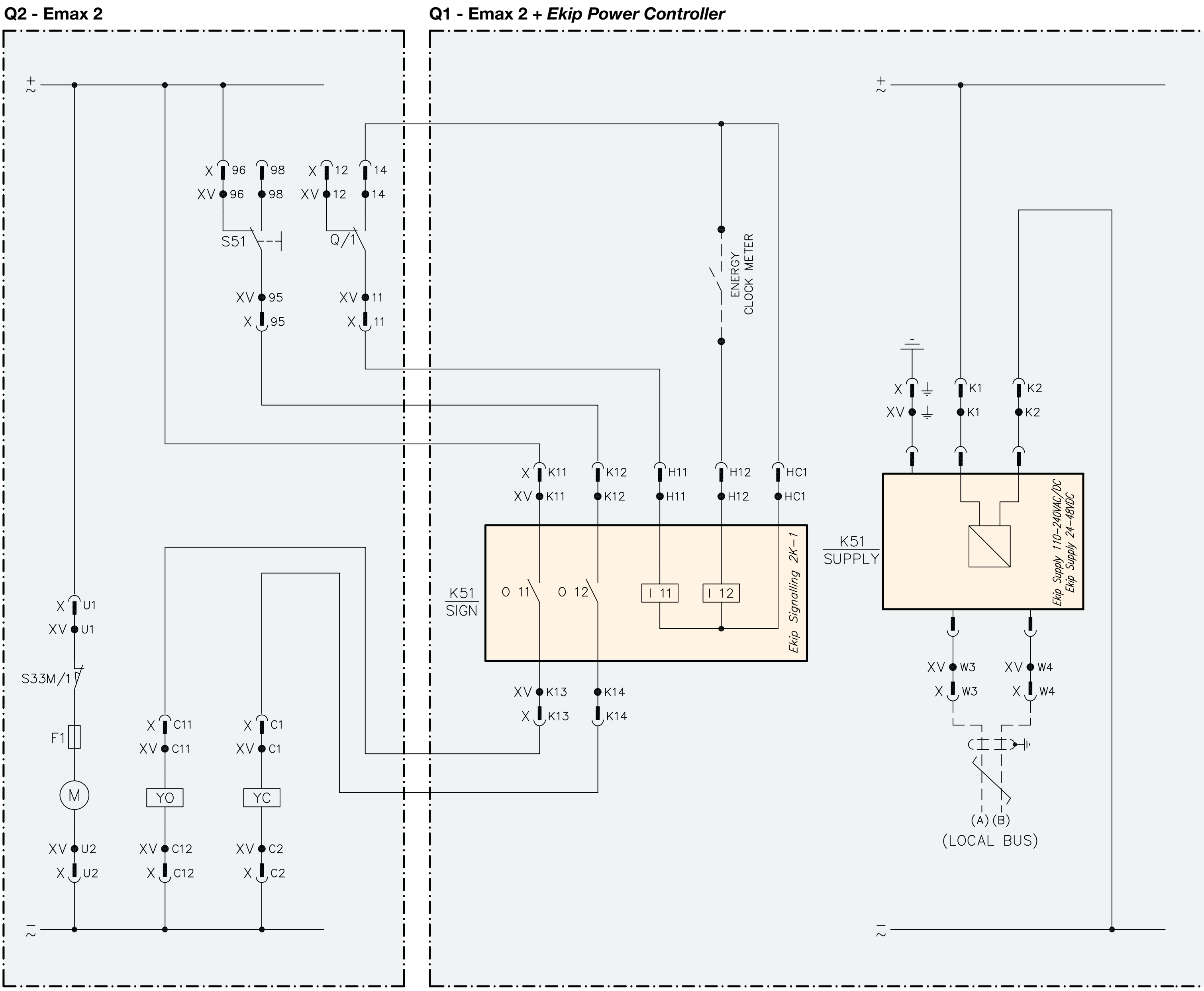
Figure 15



Energy meter clock
110.. 240 Vac
Ekip Signalling 2k
Ekip Signalling 2k
Ekip Signalling 2k
Ekip Supply
Emax 2
Ekip Signalling 4k
Ekip Power Controller
Drive
Emax 2
MS
M
Q/1
YO
YC
Tmax XT + MOE
Q/1
S51
Ekip
Tmax XT + MOE
Q/1
S51
TM
Emax 2
Ekip
M
S51
Q/1
YO
YC

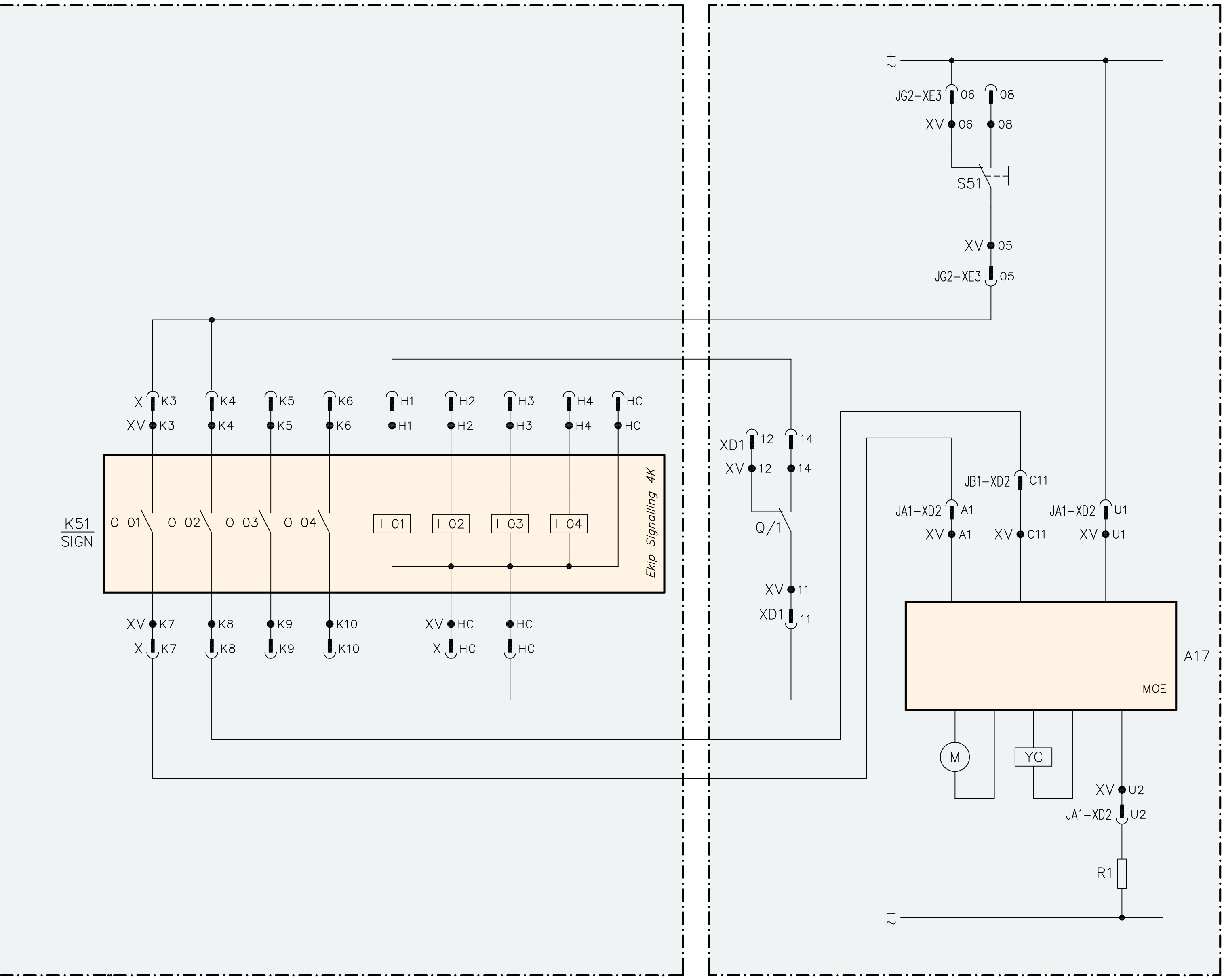
Figure 16 shows a schematic circuit diagram with an example of the connections to be carried out at the relevant terminals to connect SACE Emax 2 equipped with *Ekip Power Controller* with the two commanded circuit breakers on the load side: one is an air circuit breaker type SACE Emax 2, whereas the other is a moulded-case circuit breaker SACE Tmax XT. As can be noticed, both Ekip Signalling 2K as well as Ekip Signalling 4K modules have been used for the control to give

Figure 16



an example. When wishing to command three further circuit breakers, one of them could still be managed through Ekip Signalling 4K, whereas to manage the two remaining ones, SACE Emax 2 should be provided with *Ekip Power with Controller* with two further Ekip Signalling 2K modules. The diagram shows also the synchronization contact, which only needs to be wired to one of the Ekip Signalling modules.

Q3 - Tmax XT + MOE



4.1.2 Scenario A2 – wired connections, controlled loads > 5

When wishing to manage more than five circuit breakers (and up to 15) in the same switchboard, it is possible to use Ekip 10K mounted on DIN rail, interfacing with the main circuit breaker with *Ekip Power Controller* through the internal bus connection (connection to the terminals W3, W4 of SACE Emax 2)[5].

Up to three Ekip 10K modules can be used and each module shall be addressed through the dip switch configuration provided on the module itself.
However, cabling is provided for the circuit breakers to make it possible to command the shunt opening/closing releases and the motor operators (Figure 17).

The main circuit breaker SACE Emax 2 must be equipped with[6]:
- Ekip Power Controller function (with Ekip Measuring if the trip unit is not Hi-Touch)
- Ekip Supply module.

Each controlled circuit breaker/switch-disconnector, air type SACE Emax 2 or moulded-case type Tmax and SACE Tmax XT and each miniature circuit breaker type S800 and S200 must be equipped with the same accessories as the previous scenario.

Figure 18 shows a schematic circuit diagram with an example of the connections to be carried out at the relevant terminals to connect SACE Emax 2 equipped with *Ekip Power Controller*, the external unit Ekip 10K for DIN rail mounting and the two commanded circuit breakers on the load side: one is an air circuit breaker type SACE Emax 2 while the other is a moulded-case circuit breaker SACE Tmax XT.

When wishing to command three further circuit breakers, the above mentioned wiring must be reproduced for each additional circuit breaker. When wishing to command more than five circuit breakers instead, it would be enough to add further Ekip 10K modules (one for each group of five circuit breakers up to a total of three modules), connect them to the internal bus (by assigning an address to each of them through the relevant dip switches) and replicate the same wiring.

[5] The cable to be used is a Shielded Twisted Pair (STP), 15 m maximum length. ABB SACE specifies a cable type Belden 3105A, but the use of other types of cable with the same characteristics is allowed. The shield of the cable must be connected to earth on the CB side.
[6] In this case the synchronization signal can be delivered to one input of Ekip Signalling 10K.

Figure 17

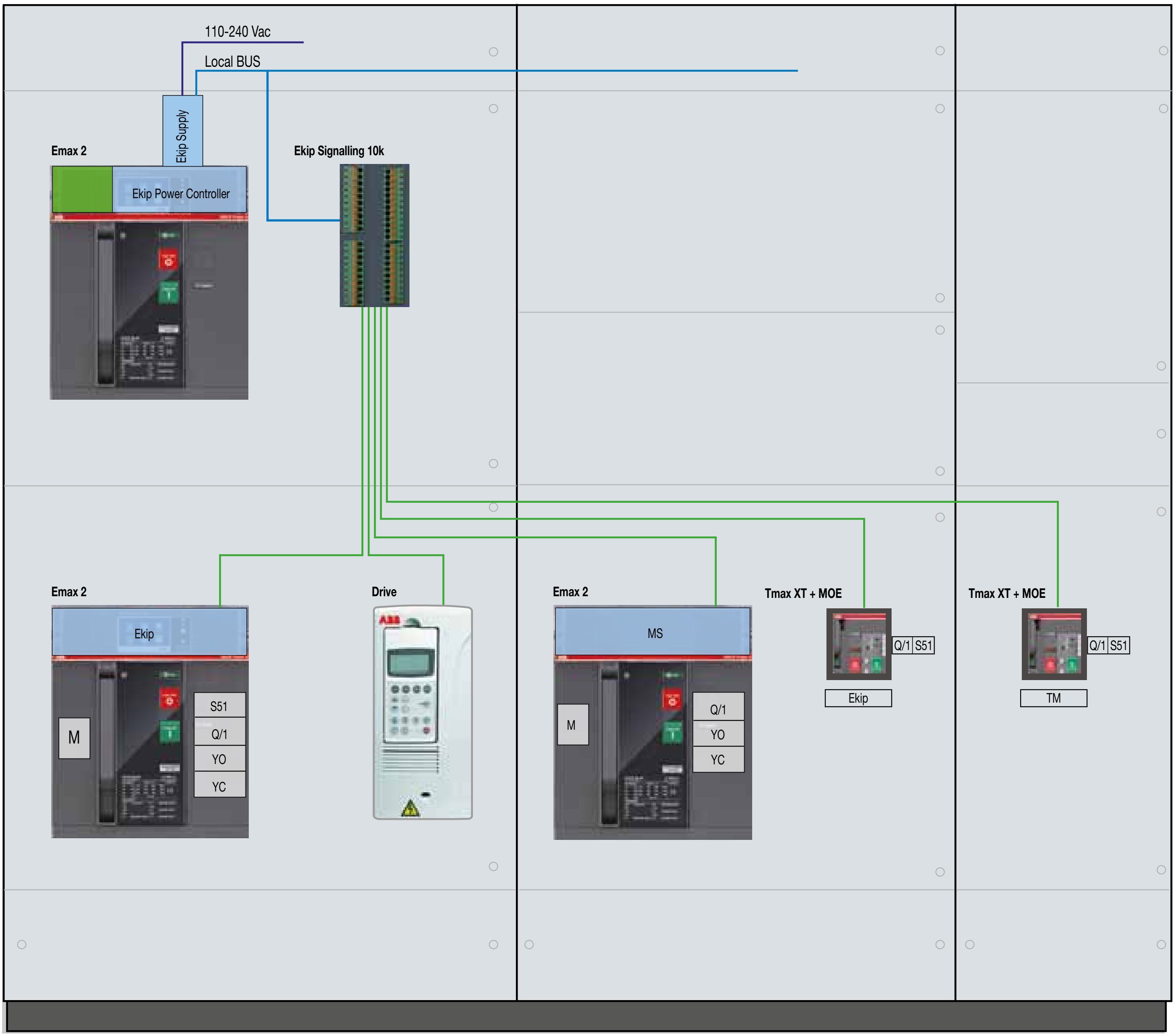
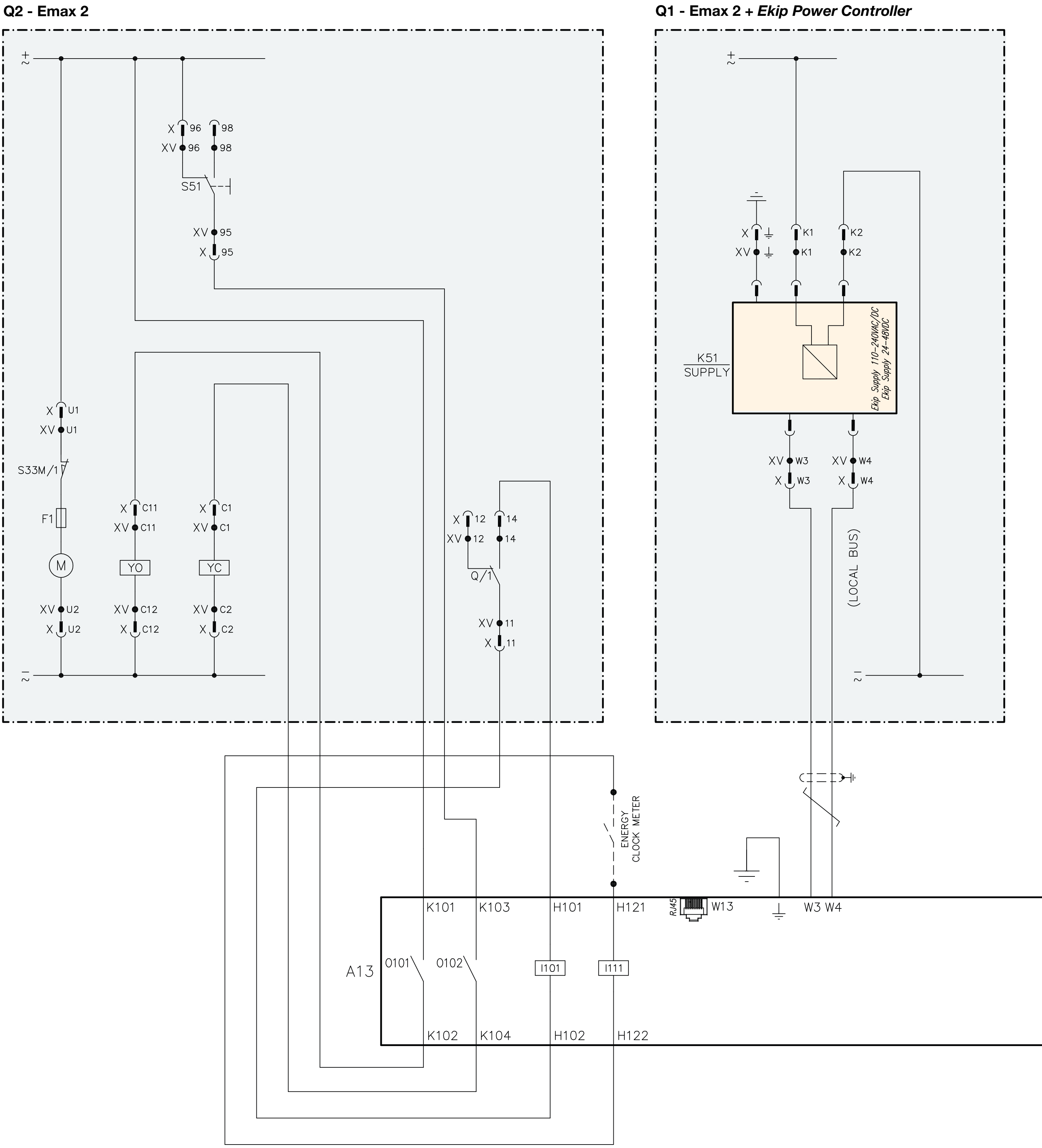
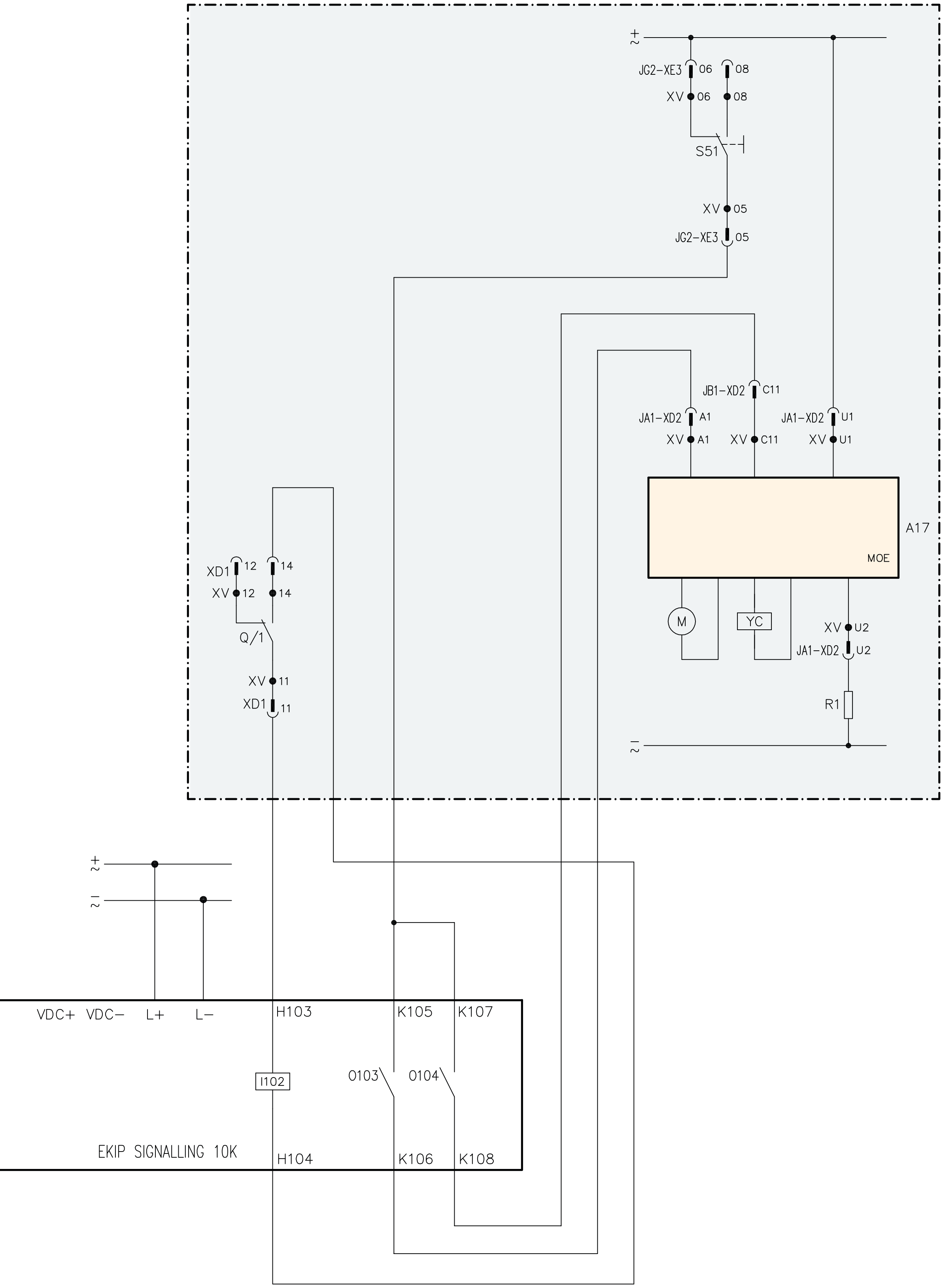

110-240 Vac
Local BUS
Ekip Supply
Emax 2
Ekip Power Controller
Ekip Signalling 10k
Emax 2
Ekip
M
S51
Q/1
YO
YC
Drive
Emax 2
MS
M
Q/1
YO
YC
Tmax XT + MOE
Q/1
S51
Ekip
Tmax XT + MOE
Q/1
S51
TM

Figure 18


Q2 - Emax 2
Q1 - Emax 2 + Ekip Power Controller
S51
S33M/1
F1
M
YO
YC
Q/1
K51
SUPPLY
Ekip Supply 110-240VAC/DC
Ekip Supply 24-48VDC
(LOCAL BUS)
ENERGY
CLOCK METER
A13
K101
K103
H101
H121
RJ45
W13
W3 W4
O101
O102
I101
I111
K102
K104
H102
H122

Q3 - Tmax XT + MOE



4. Settings and connections

4.2 Scenario B: different switchboards

4.2.1 Scenario B1 – connection to SACE Emax 2 circuit breakers through Ekip Link

As for wiring, if the circuit breakers/switch-disconnectors of the controlled loads are SACE Emax 2 type installed in different switchboards, it is easier and less expensive to perform communication and control through Ekip Link connection, which allows long-distance management. In such case, each circuit breaker must have auxiliary supply. However, there is the possibility of commanding other circuit breakers in the same switchboard by using the same wiring described in the scenario A1 (Figure 19).

The main circuit breaker SACE Emax 2 must be equipped with:

- *Ekip Power Controller* function (with Ekip Measuring if the trip unit is not Hi Touch)
- Ekip Supply module
- Ekip Link module[7]
- Ekip Signalling module for clock synchronization with the smart meter of the DSO (optional).

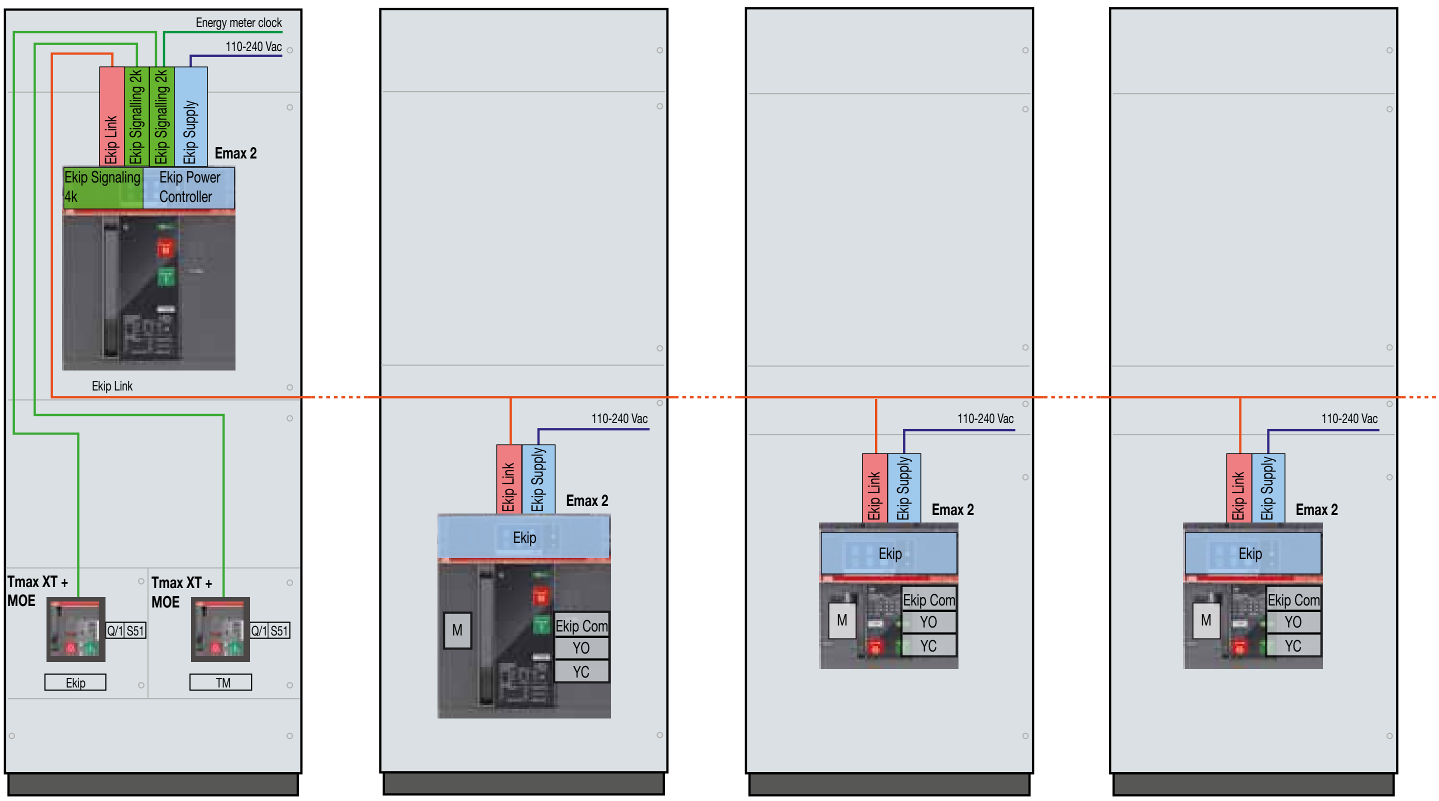
Each controlled air automatic circuit breaker or switch-disconnector type SACE Emax 2 must be equipped with:

- Ekip Supply module
- Ekip Link module
- shunt opening release (YO)
- shunt closing release (YC)
- geared motor for automatic charging of the closing springs (M)[8]
- internal Ekip Com Actuator.

[7] Customers must guarantee the presence of an Ethernet Switch with a number of outputs depending on the number of circuit breakers/switch-disconnectors to be controlled

[8] However, the supply of the shunt opening/closing releases YO and YC and of the spring charging motor must be provided.

Figure 19



4.2.2 Scenario B2 – Connection through Ekip Link to SACE Emax 2 circuit breakers and to Ekip Signalling 10K

Regarding applications with different switchboards, in which circuit breakers and switch-disconnectors series Emax, Tmax and Tmax XT and/or miniature circuit breakers are installed, it is possible to use Ekip Signalling 10K equipped with an interface for Ekip Link through standardized Ethernet cable, e.g. STP cable and RJ45 connector (Figure 20).

The main circuit breaker SACE Emax 2 must be equipped with:

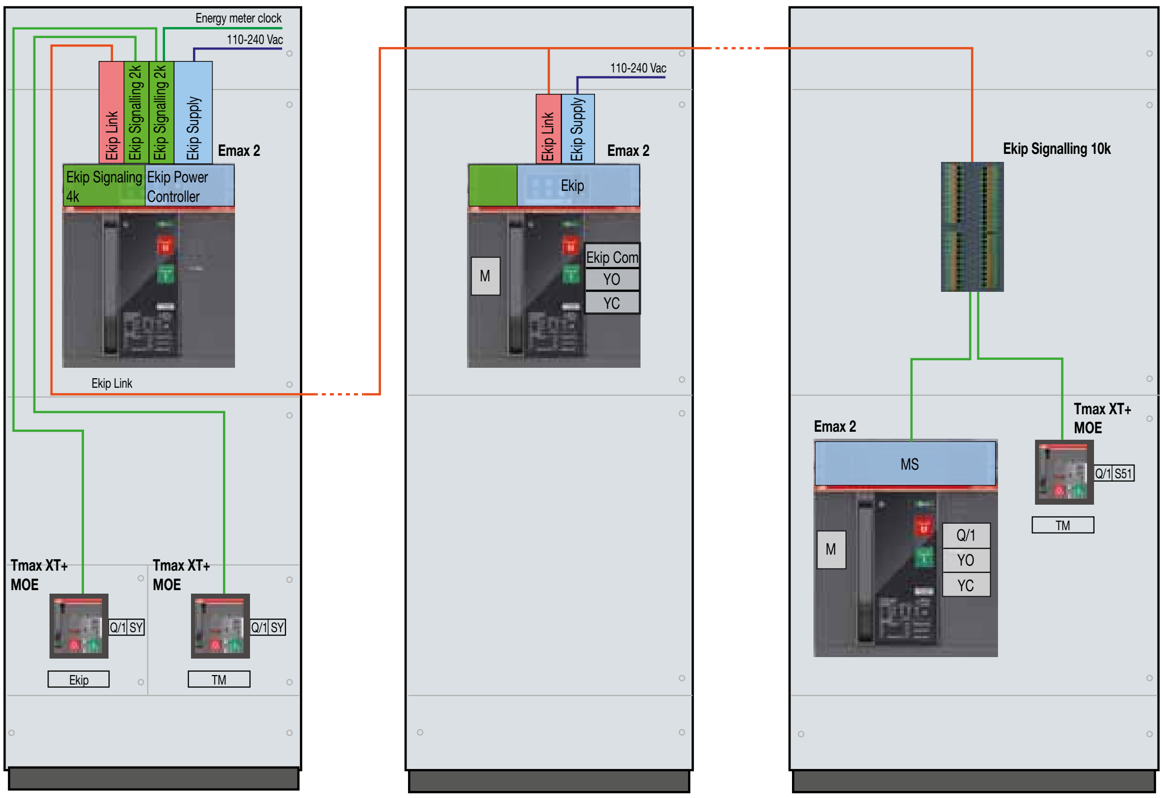
- *Ekip Power Controller* function (with Ekip Measuring if the trip unit is not Hi Touch)
- Ekip Supply module
- Ekip Link module and/or Ekip Signalling module
- 1 digital input for clock synchronization with the smart meter of the DSO (optional).

Each air circuit breaker type SACE Emax 2 controlled through Ekip Link must be equipped with the same accessories as the previous scenario.

Each circuit breaker/switch-disconnector, both air type SACE Emax 2 as well as moulded-case type Tmax and SACE Tmax XT and each miniature circuit breaker S800 and S200 controlled through Ekip Signalling 10K module, must be equipped with the same accessories as scenario A2.

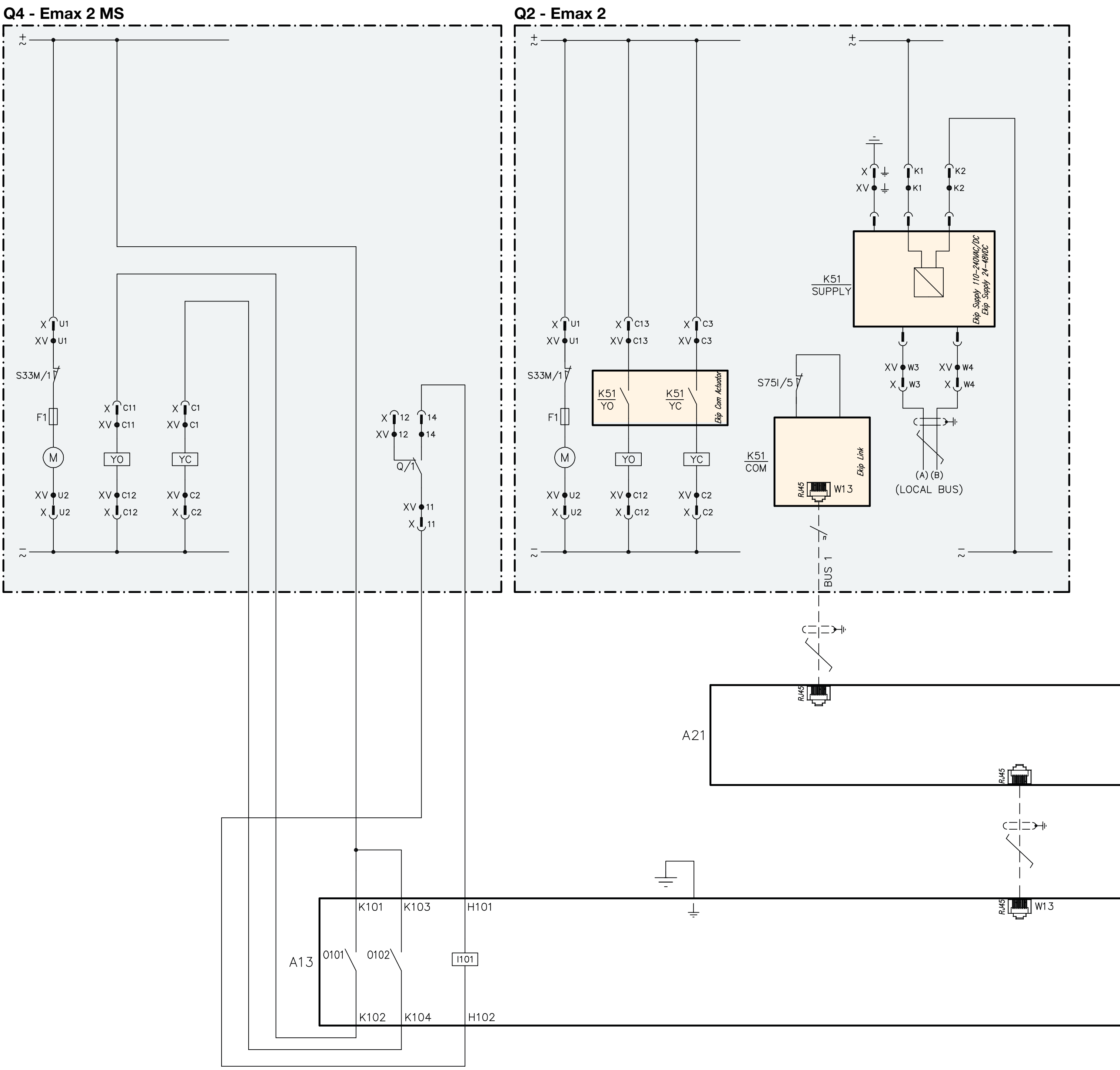
Figure 21 shows a schematic circuit diagram with an example of the connections to be carried out at the relevant terminals

Figure 20



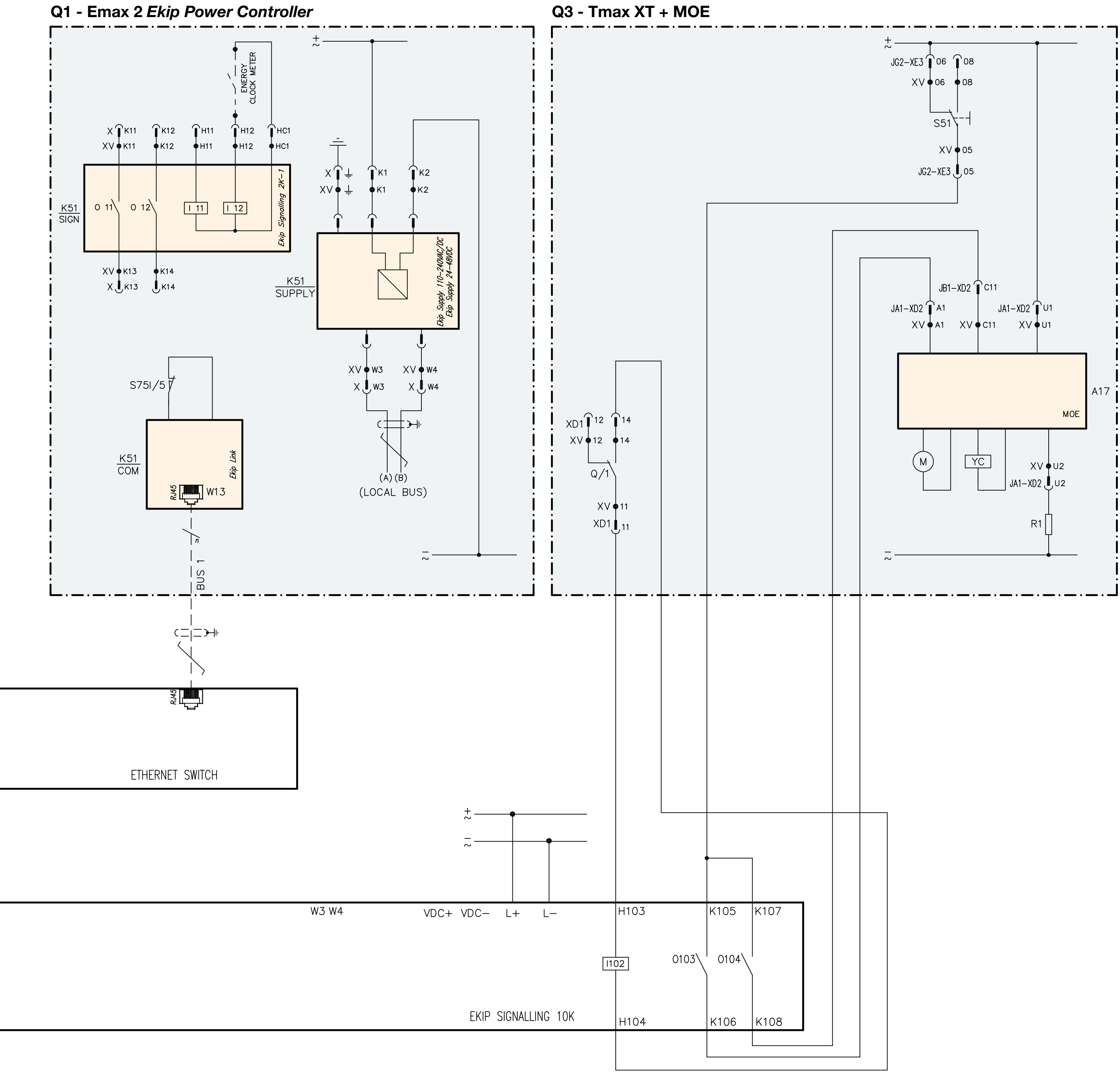
to connect SACE Emax 2 equipped with *Ekip Power Controller* with three circuit breakers on the load side installed in other switchboards and commanded through Ekip Link: one is an air circuit breaker type SACE Emax 2, the second one is a switch-disconnector SACE Emax 2, while the third is a moulded-case circuit breaker SACE Tmax XT. As can be seen from the diagram, through Ekip Link (and one Ethernet Switch) it is possible to command directly one SACE Emax 2 (without additional cabling) or making the connection with Ekip Signalling 10K for the wired management of other circuit breakers. In particular, SACE Emax 2 circuit breakers commanded through Ekip Link must be supplied by the shunt opening and closing releases through Ekip Com Actuator contacts.

Figure 21



4.3 Scenario C: connection with two transformers

In a plant with two MV/LV transformers it is possible to install only one circuit breaker equipped with *Ekip Power Controller* on the LV bus riser of one of the two transformers, without having to duplicate wiring (Figure 22). As for the second circuit breaker, it will be enough to connect it to Ekip Link and to mount Ekip Supply and Ekip Measuring modules, whereas on the first circuit breaker equipped with *Ekip Power Controller* it will be enough to add the IP address of the second circuit breaker in Ekip Connect so that it is possible to read the quota of the absorbed energy passing through it.



4. Settings and connections

Then, the first circuit breaker shall carry out the analysis (and the consequent load management) of the total energy consumed in the plant; this total energy is the sum of the two energy profiles detected by the two measure modules. In particular, if the two transformers operate in an alternate way, when the second transformer is put into service, the first circuit breaker carries out the analysis of the energy which has been absorbed by the plant and which, in this case, flows exclusively through the second circuit breaker (Figure 23).

One of the two main circuit breakers SACE Emax 2 must be equipped with:
- *Ekip Power Controller* function (with Ekip Measuring if the trip unit is not Hi Touch)
- Ekip Supply module
- Ekip Link module and/or Ekip Signalling module
- 1 digital input for clock synchronization with the smart meter of the DSO (optional).

The other SACE Emax 2 circuit breaker must be equipped with:
- Ekip Measuring with Hi Touch trip unit
- Ekip Supply module
- Ekip Link module.

Each controlled circuit breaker/switch-disconnector and miniature circuit breaker must be equipped with the same accessories as in the previous scenario.

Figure 22

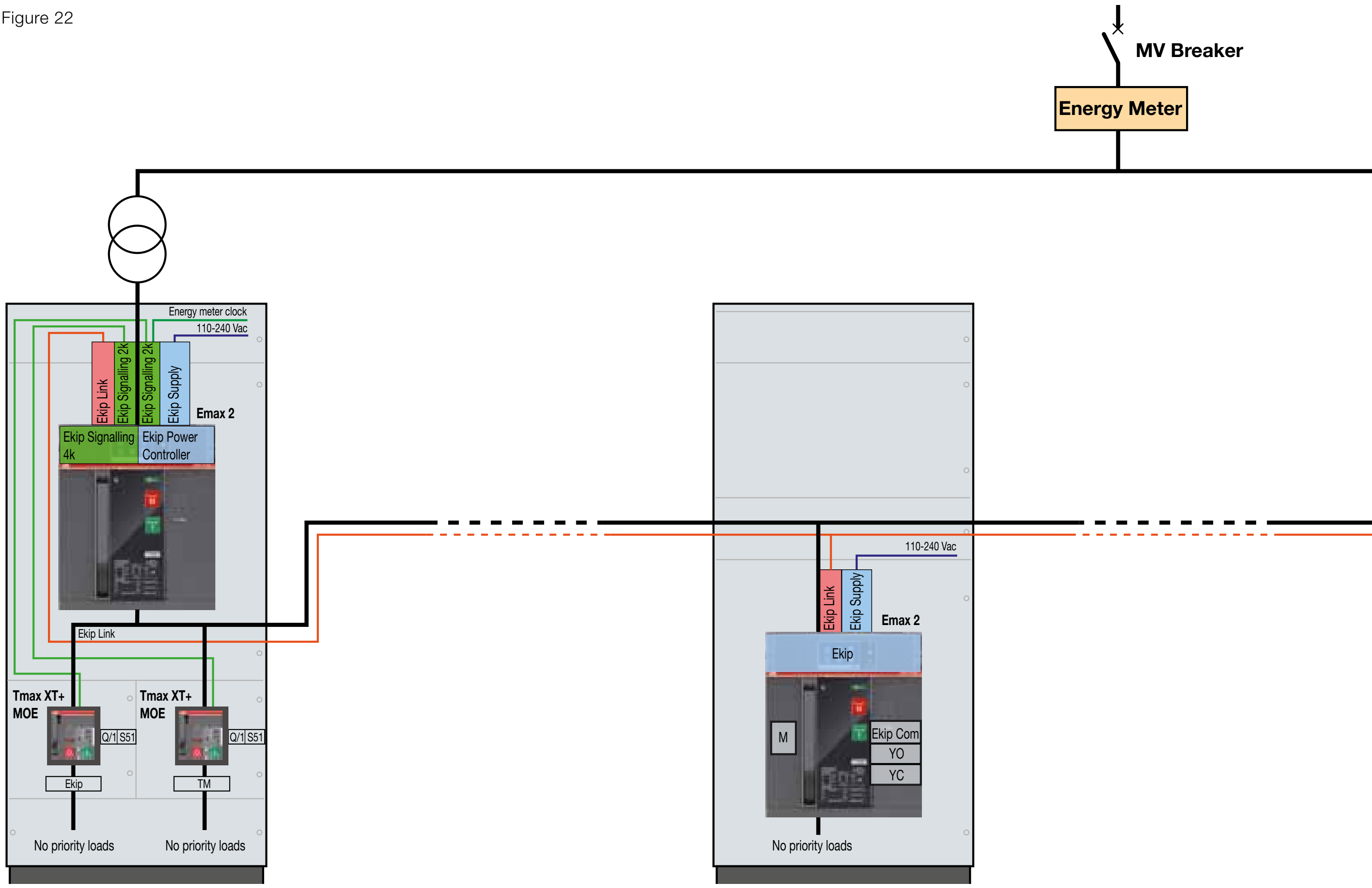
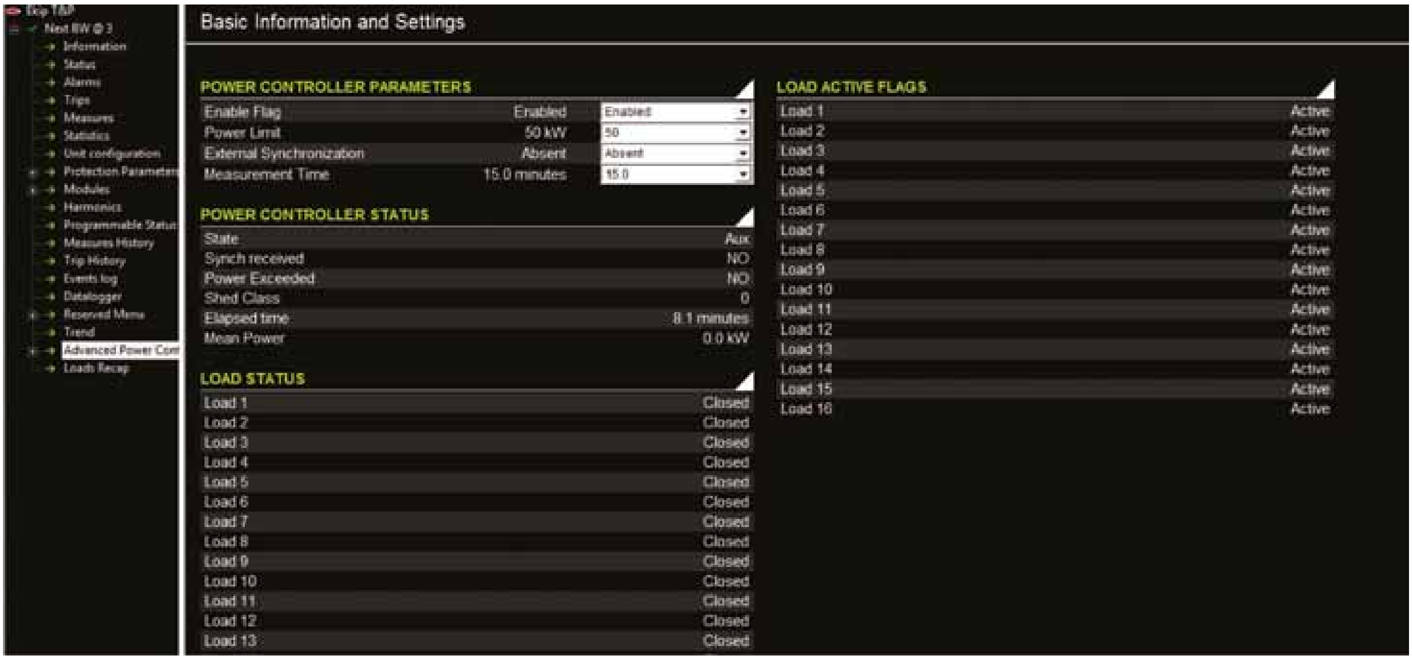
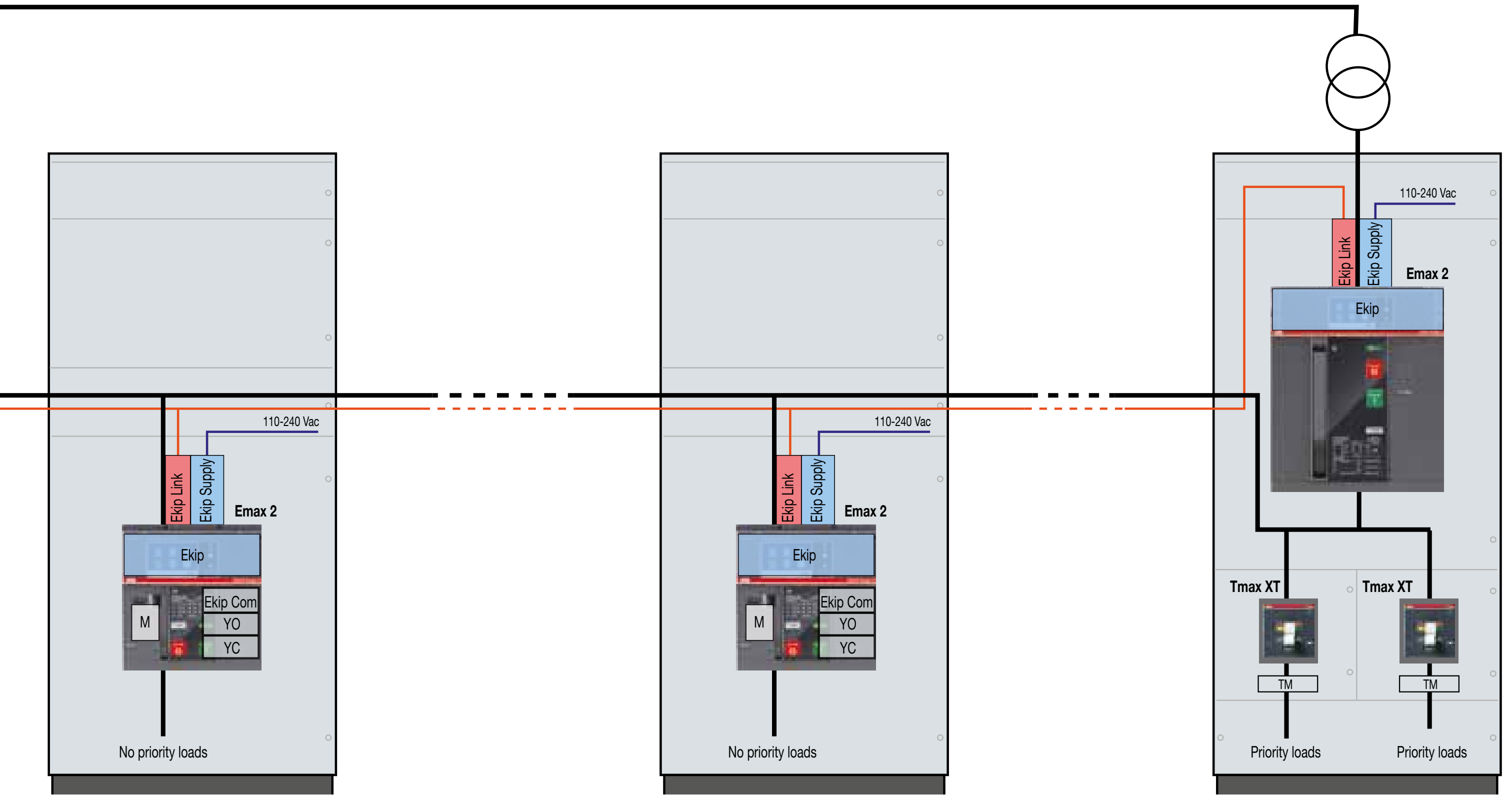


Figure 23


Basic Information and Settings
Information
Status
Alarms
Trips
Measures
Statistics
Unit configuration
Protection Parameters
Modules
Harmonics
Programmable Status
Measures History
Trip History
Events log
Datalogger
Reserved Menu
Trend
Advanced Power Cont
Loads Recap
POWER CONTROLLER PARAMETERS
Enable Flag Enabled Enabled
Power Limit 50 kW 50
External Synchronization Absent Absent
Measurement Time 15.0 minutes 15.0
POWER CONTROLLER STATUS
State Aux
Synch received NO
Power Exceeded NO
Shed Class 0
Elapsed time 8.1 minutes
Mean Power 0.0 kW
LOAD STATUS
Load 1 Closed
Load 2 Closed
Load 3 Closed
Load 4 Closed
Load 5 Closed
Load 6 Closed
Load 7 Closed
Load 8 Closed
Load 9 Closed
Load 10 Closed
Load 11 Closed
Load 12 Closed
Load 13 Closed
LOAD ACTIVE FLAGS
Load 1 Active
Load 2 Active
Load 3 Active
Load 4 Active
Load 5 Active
Load 6 Active
Load 7 Active
Load 8 Active
Load 9 Active
Load 10 Active
Load 11 Active
Load 12 Active
Load 13 Active
Load 14 Active
Load 15 Active
Load 16 Active


110-240 Vac
Ekip Link
Ekip Supply
Emax 2
Ekip
M
Ekip Com
YO
YC
No priority loads
110-240 Vac
Ekip Link
Ekip Supply
Emax 2
Ekip
M
Ekip Com
YO
YC
No priority loads
110-240 Vac
Ekip Link
Ekip Supply
Emax 2
Ekip
Tmax XT
Tmax XT
TM
TM
Priority loads
Priority loads

5. Application example

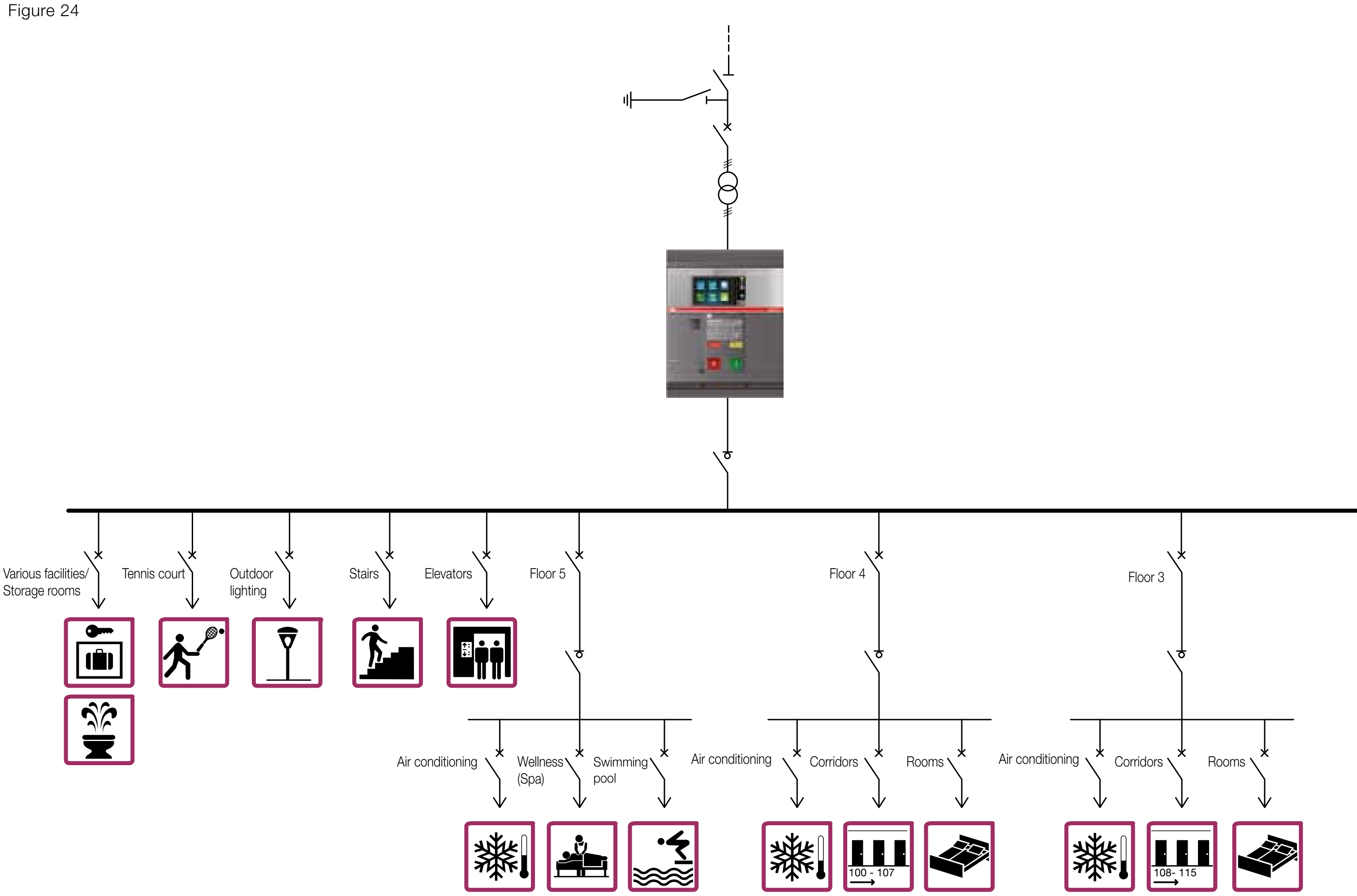
The following example illustrates a practical application of load management in a plant in which *Ekip Power Controller* is used to decrease the maximum power demand from the network and therefore to reduce the contractual power agreed upon with the DSO with consequent economic savings.
In particular, this example refers to a 4 star air-conditioned hotel complex, consisting of 80 rooms (20 on each floor), connected to a MV 15 kV network through its own transformation substation. The complex comprises private underground parking, swimming pool, wellness center (spa), tennis court and outdoor parking.
The monthly average consumption is about 150 MWh and a power factor correction plant is installed to keep the monthly average power factor equal to or higher than 0.9.

During high season period maximum total power absorption of about 578 kW has been detected. The following table is the result of a more detailed analysis of the power demand of the different types of load:

Table 1 – Power absorbed [W] according to the type of load

Rooms	168000
Corridors	3600
Stairs	2880
Hall	4800
Kitchen (electric stoves/ovens, refrigerators, freezers)	16000
Restaurant	19200
Bar	4200
Elevators	32400
Air-conditioning	208320
Laundry	8400
Swimming pools	32000
Wellness center / Spa	32000
Congress room	14400
Storage rooms and various facilities	9600
Tennis courts (night lighting)	4800
Outdoor lighting	12000
Underground car parking	6000
	578600

Figure 24



Therefore, in order to reduce the maximum contractual power agreed upon with the DSO, through *Ekip Power Controller* function the aim is to decrease the maximum power absorption at 500 kW.
Then, it is the task of *Ekip Power Controller* function of SACE Emax 2 to disconnect/reconnect the defined loads in order not to exceed the contractual power in the hour bands.
The selected loads, which could be disconnected for some minutes and therefore managed by *Ekip Power Controller* according to the priority list defined by the User, are the following:
- air conditioning system considered per floor
- water heating systems and swimming pool circulation pumps
- heating in sauna, turkish bath, hydromassage areas
- electric stoves/ovens
- laundry
- freezers
- refrigerators
- reduction in the lighting of the underground parking and outdoor.

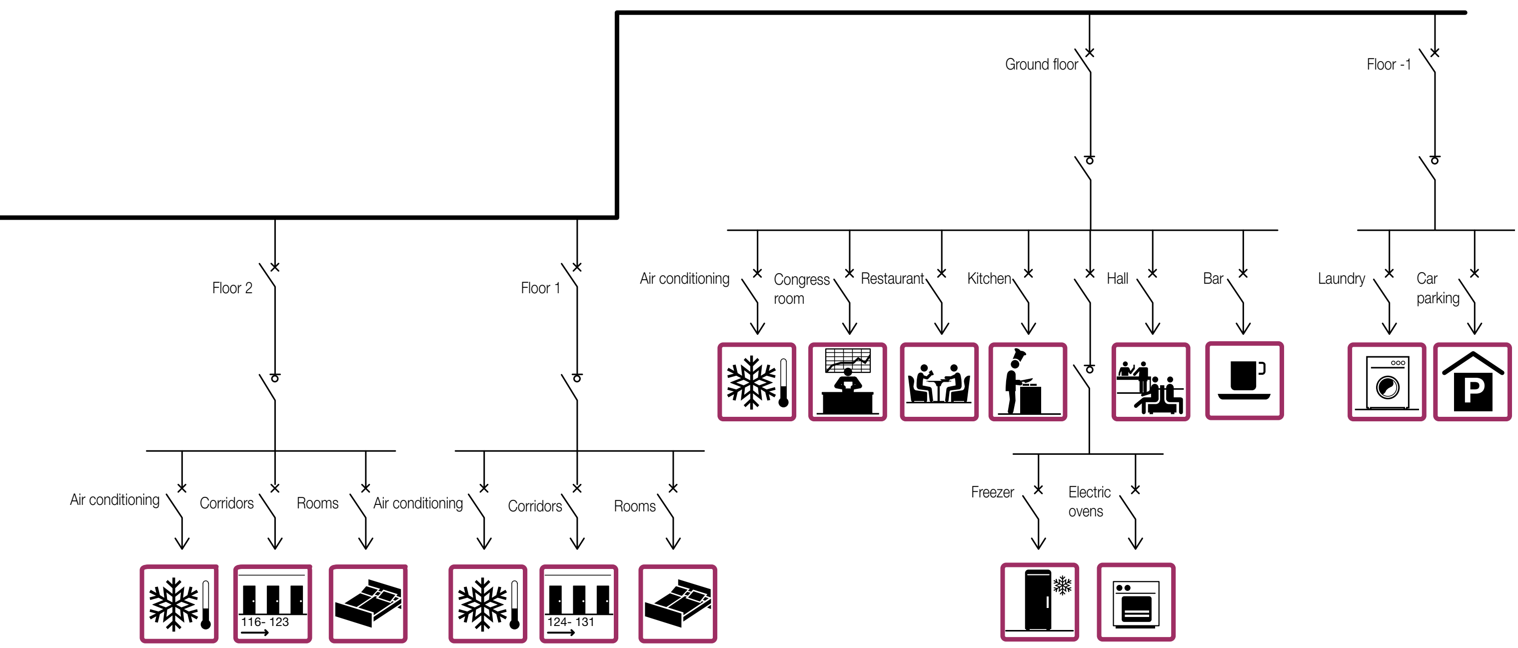
The main electrical diagram (Figure 24) showing the different circuit breakers which command/protect the supply lines of the various loads is given below:

Taking into consideration different countries, Table 2 shows some examples of the annual savings that can be obtained on the power quota thanks to *Ekip Power Controller* function[9].

Table 2

	Annual costs [€]		Annual
Contractual power	580 kW	500 kW	savings [€]
Italy	16261.75	14018.75	2243.00
Spain	18513.60	15960.00	2553.60
China	15590.40	13440.00	2150.40
India	17748.00	15300.00	2448.00
Brazil	20949.60	18060.00	2889.60
USA (Wisconsin)	75980.00	65500.00	10480.00
Canada	87278.40	75240	12038.40

[9] Local currencies have been converted into Euros to express the annual costs. For a thorough economic analysis on the investment return the various up-to-date annual savings and the initial costs for equipping the circuit breakers and for additional wiring should be taken into consideration.



6. FAQ

• **Where is the *Ekip Power Controller* function installed?**
This function is integrated in the electronic trip unit of the main circuit breaker of the LV plant of the User and it measures the total energy consumed by the network

• **What is the synchronization of *Ekip Power Controller* with the energy meter used for and why is it necessary?**
Ekip Power Controller keeps the average consumed power under control in each pre-defined time interval (e.g. 15 minutes), independently of the presence of the synchronization signal. However, when you want the energy meter and the algorithm of *Ekip Power Controller* to use comparable measures (to avoid exceeding the contractual power limit), it is necessary that they use the same time intervals and start measuring at the same instant: therefore a synchronization of the two clocks is necessary.

• **How many loads can be present in a plant?**
Ekip Power Controller can switch and control up to 15 loads. For each of them, *Ekip Power Controller* commands the disconnection and reconnection operations of the supply whenever necessary so that the average power can be maintained within the defined limits in the established period. However, besides these loads, the electrical plant may include any number of loads independent of *Ekip Power Controller.*

• **Why *Ekip Power Controller* system is more efficient than the system based on the maximum absorbed current?**
The instantaneous active power consumed by a plant depends on the current, on the voltage and on the power factor. The systems that use current as a quantity to be measured in order to keep power under control are generally based on precautionary calculations which consider the highest possible power at certain current value.
For example, a plant supplied through a 15000/400 V transformer with unit power factor and 1000 A current consumes
$P = \sqrt{3} VI \cos\varphi = \sqrt{3} \cdot 400 \cdot 1000 \cdot 1 = 693 kW$.
A current-based load control system will evaluate such power consumption if the current measured is 1000 A.
But, if the power factor is lower than 1, which generally occurs when supplying motors, the power which is actually consumed is lower. Therefore the control system could estimate a power value higher than the effective one, thus disconnecting some loads when it is not needed.
Ekip Power Controller instead, evaluates the average power in the period and allows the maximum power limit to be exceeded for a short time, provided that the total energy in the considered period is lower than the product obtained multiplying the average power by the period.
As a consequence, *Ekip Power Controller* permits a better energetic exploitation of the plant in comparison with a maximum-current-based system.

• **Is *Ekip Power Controller* system affected by harmonics?**
In modern installations, the ever growing presence of electronic devices causes both current and voltage harmonics which affect the active power absorbed. However, since *Ekip Power Controller* uses power measures based on synchronized sampling of current and voltage values, the algorithm gets the instantaneous power and the consumed energy independent of whether or not harmonics are present.

• **How are the controlled loads operated?**
Ekip Power Controller operates by connecting and disconnecting the loads from supply. Such connection and disconnection operations are performed by an automatic circuit breaker or by a switch-disconnector or by a contactor or by a control circuit for each load. It is also possible to connect more loads downstream of a switching device, but in that case the loads will be connected or disconnected all together since *Ekip Power Controller* shall consider them as a single load.

- **How does *Ekip Power Controller* decide which loads are to be disconnected?**

Before activating *Ekip Power Controller*, the User defines the priority list for the disconnection of loads. This means matching each load to a number starting from 1 (the first load to be disconnected in case of need) up to number 15 (the last load to be disconnected). *Ekip Power Controller* shall always carry out disconnection from the first load available in the list (that is according to the respect times and the temporarily unavailability of one or more loads due to manual opening or tripping of the protection device) and following the numerical order.

- **What happens if a momentary power peak occurs (for example a motor starts up)? Are some of the loads disconnected?**

Ekip Power Controller operates on the basis of the average power consumed in a determined period of time (adjustable by the operator – e.g. 15 minutes). In the event of temporary increases in the absorbed power (e.g. when starting up a motor for a few seconds), *Ekip Power Controller* evaluates how they affect the average value: since the effect is usually limited, *Ekip Power Controller* does not give any disconnection command of the load.

- **Is it possible that the device controlled by Ekip Power Controller or the load managed by it is damaged due to too frequent connection/disconnection operations?**

For each load, *Ekip Power Controller* defines minimum time intervals (adjustable) between an operation and the further one. These intervals are foreseen first of all to ensure that the electrical and mechanical transient due to start-up/stop operations extinguishes, so that the load can operate properly. The time intervals must be chosen by the User taking into consideration also the type and characteristics of each load (for instance, it is likely that a refrigerator, once switched on, must be kept running for at least ten minutes without interruptions).
Ekip Power Controller ensures that such limits are complied with, thus guaranteeing that the load is not switched too frequently. In particular, open-closed “bounces” are prevented from occurring since they are sometimes the cause of damages in automatic connection/disconnection systems.

- **Is it necessary to change or define particular settings for the protection functions against the overcurrents in the automatic circuit breakers controlled by *Ekip Power Controller*?**

No, because protection devices intervene in the event of overload or short circuit, whereas *Ekip Power Controller* functions under standard operating conditions and therefore it does not interfere with them. In fact, *Ekip Power Controller* perfectly integrates with the time-current and energy selectivity realized with the installed circuit breakers: the selectivity level specified for the plant is maintained and it is not necessary to vary the protection settings.

Contact us

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