

White paper - Preliminary

Emax 2, all-in-one innovation Synchro Reclosing

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Emax 2

Synchro Reclosing

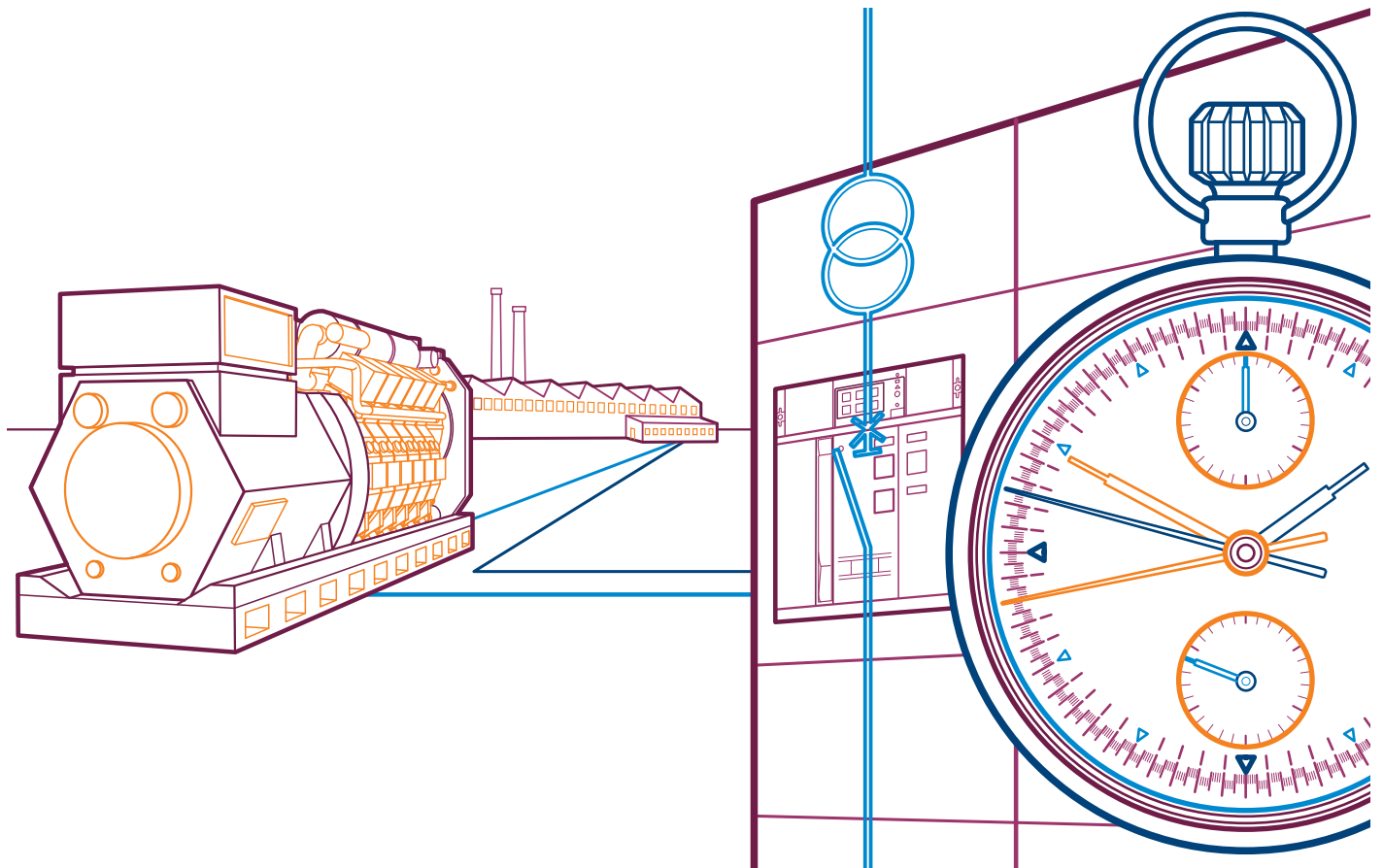
Introduction

The electrical distribution is evolving from the traditional top-bottom grid configuration to the next level approach with distributed energy resources. Besides big powerhouses, a constellation of small-scale generators modifies the power flow, giving space for production and consumption located at the same low voltage layer. The short source-to-load distance ensures the electrical system reliability, reducing the lines for the power transmission, increasing the energy autonomy and improving the power quality. Microgrid trend is the transformation of the system topology, ensuring the revolution in the age of the digital energy. By definition, a Microgrid is a low voltage network able to work either connected to the medium voltage grid or islanded. For this reason, it guarantees power supply flexibility for utilities and power producers, besides a great capability for resiliency in the presence of weak distribution network, such as in remote locations with electrification gaps.

All of this is possible thanks to advanced integration among devices and machines in terms of monitoring and control. In particular, the interface with the main grid is crucial to get all the Microgrid targets. Circuit breakers are not only basic protection components of the electrical layout, but they assume the responsibility of the Microgrid resources management, as protagonists of the plant disconnection and reconnection.

The scope of this White Paper is to explain how ABB Emax 2 manages two fundamental Microgrid operations using its embedded functions and logics in order to perform:

- Automatic Synchronization of the Microgrid supported by Emax 2 which moves up or down the local generation according to the measurements at the interface point with the main grid.
- Automatic Reclosing to the main grid of the interface circuit breaker, Emax 2, when the main grid achieves the stability and the conditions comply with the synchronism settings, easily suggested during the commissioning stage.



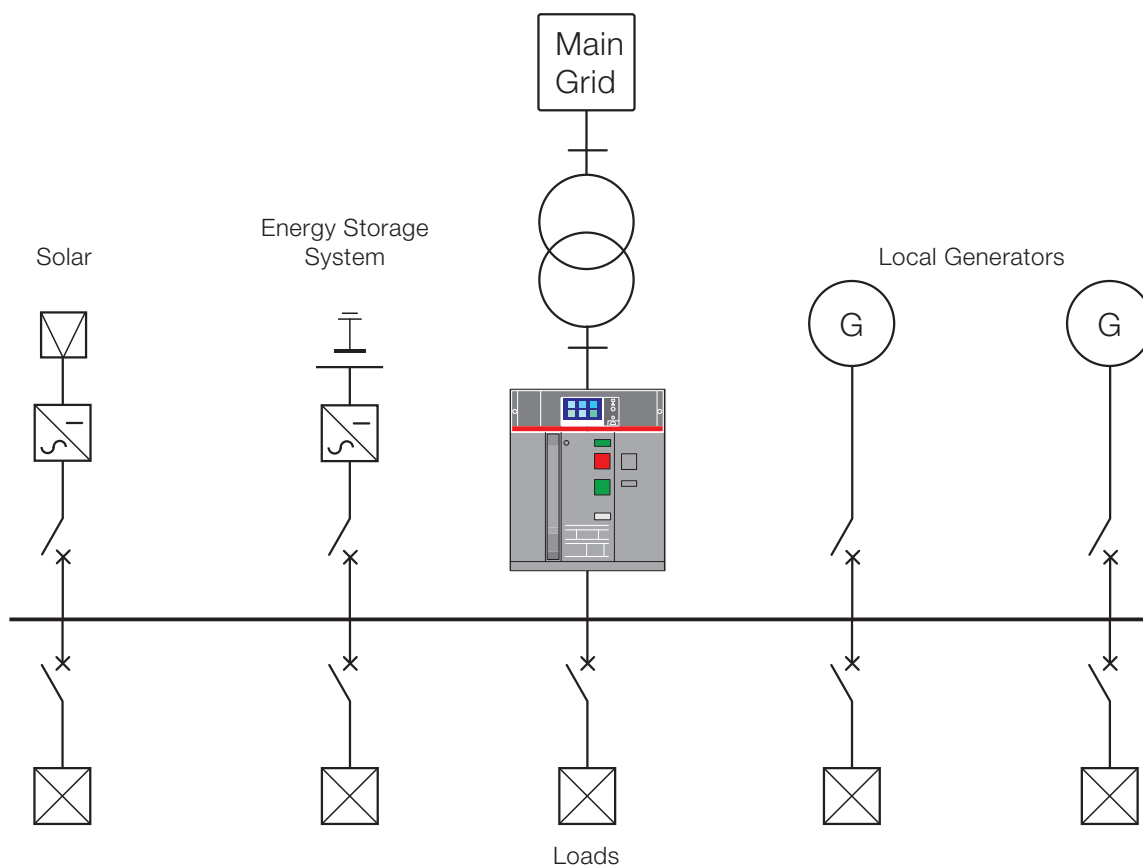
Emax 2 all-in one innovation

ABB Emax 2 is the all-in-one innovation that makes Microgrid simpler and more cost-effective, embedding advanced software based solutions for protection, monitoring and control. Thanks to its advanced electronics, Emax 2 is the first smart circuit breaker able to island the Microgrid from disturbances such as in the presence of faults or power quality events¹ and reconnect it to the distribution network, when there are the right conditions. This last feature makes an islanded Microgrid be reconnected to the main grid, supporting the synchronization and detecting the synchronism situations for the automatic re-closure even in strict requirement scenarios.

Emax 2 unlocks all these functions allowing space savings for panel builders and O&M GenSet manufacturers, meanwhile the ease of use is guaranteed for consultants and system integrators, avoiding possible barriers for the widespread dissemination of Microgrid projects.

¹ See White Paper 1SDC007119G0201 - Load Shedding.

Figure 1: low voltage Microgrid



Emax 2

Synchro Reclosing

Benefits

Space savings

Neither external units, nor strong engineering efforts are required as Emax 2 implements new functions in its intelligent trip units and internal modules maintaining the ease of use and introducing more protections and algorithms. The circuit breaker is a protection device always present in the electrical distribution, so that panel builders can reduce the cabinets required for low voltage substation switchgear and O&Ms GenSet manufacturers can optimize the footprint required for Microgrid solutions.

No synchrocheck relay, no synchronizing equipment are required for paralleling operation. Voltage sensors at the Microgrid side are integrated in the circuit breaker, so only one single-phase transformer is requested at the main grid side. The logics are all inside the trip unit and the user does not need programming and engineering skills. For all these reasons, Emax 2 is the first compact Microgrid solution with embedded advanced capabilities, that guarantees less components in every condition (Figure 2, Figure 3).

Figure 2: many components required without Emax 2

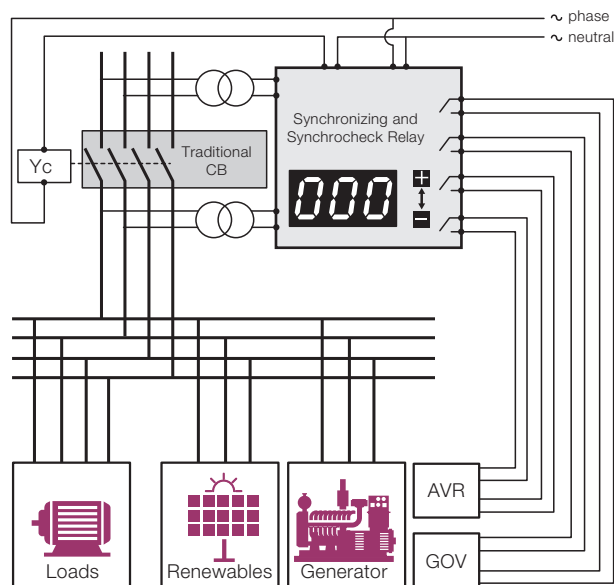
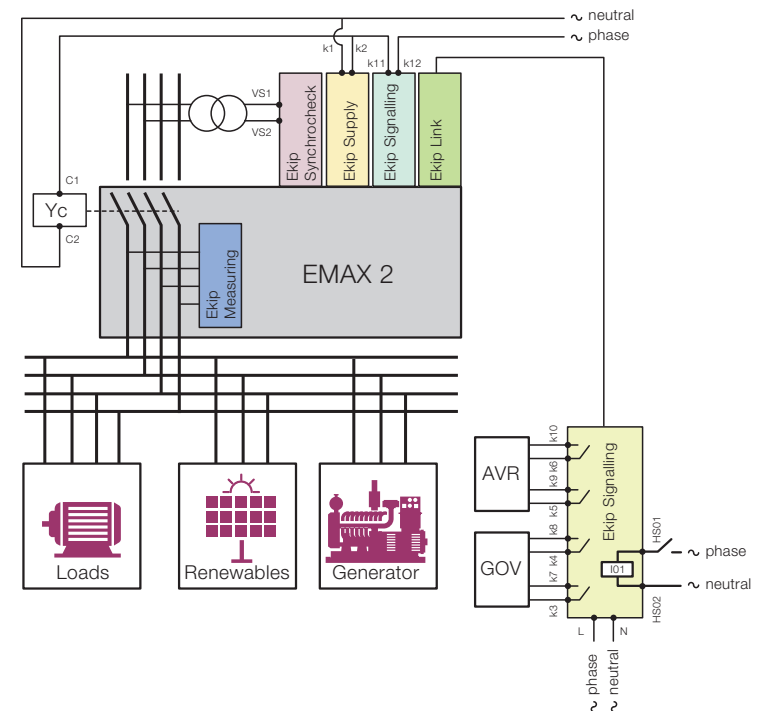


Figure 3: few components required with Emax 2



Ease of use

The all-in-one concept means also less time for the commissioning, if compared with external devices that need cabling effort and system integration. Emax 2 offers a complete plug-in function for new plants minimizing installation time and miscabling. The easy approach is enabled by predefined configuration template that unlocks the product feature even after-sales if equipped with right hardware accessories. The setting definition is simplified thanks to an easy software tool running on a laptop: it suggests the parameters depending on the specific Microgrid case, without touching the device (Figure 4, Figure 5). Giving only a few inputs about the plant layout, the consultants receive indications for the main synchronism parameter settings, in order to ensure a double check with their plant designs and speed up the projects.

Figure 4: commissioning without Emax 2

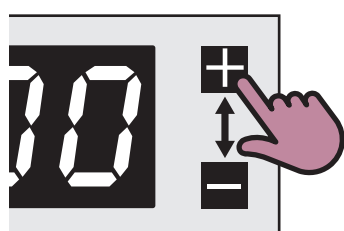


Figure 5: commissioning with Emax 2



How it works

Emax 2 is the unique circuit breaker with automatic synchro reclosing. This function consists in synchronization support of the Microgrid reconnection operation or generator paralleling procedure as prescribed by Std. ANSI 25A, with additional reclosing capabilities based on the Ekip Synchrocheck state.

Using the Ekip Synchrocheck cartridge module (see Annex A), Emax 2 monitors the most important reconnecting parameters and realizes simple logics to adapt the Microgrid voltage and frequency to the main grid ones. The secondary regulation of the local generators is realized by Ekip Signalling contacts (see Annex B) to reach synchronization. The circuit breaker automatically recloses when it understands that the synchronism is achieved using Ekip Synchrocheck and the integrated closing coil. Sometimes this operation can be very critical, because the current following during the transient of the reconnection must not reach values that can potentially cause the Microgrid shut down. In other words, the reclosing phase is like the parallel of two different steady state sources: when the interface circuit breaker closes, a transient occurs, during which over currents have to be limited, otherwise, unwanted trips of the generator protections may occur. With the aim to avoid complex analysis and customizations, Ekip Connect commissioning tool completes the Synchro Reclosing functionality, recommending the right settings according to the plant configuration. In general, this application is useful in the following plant-engineering situations:

- during the Microgrid reconnection to the main grid, speeding up the paralleling procedure between two systems with different steady states. This scenario comes after the islanding Microgrid operation;
- when there is the closed transition of an automatic transfer switch, the main grid should be connected to the same bus-bar with the backup Microgrid generation in order to guarantee continuous load operation, with or without a bus-tie circuit breaker²;
- besides Microgrid case, it is possible to adopt this solution also for single GenSet paralleling operation³.

² An example of ATS closed transition embedded in Emax 2 circuit breaker is described in White Paper 1SDC007115G0201.

³ In this White Paper, this application case is considered similar to the Microgrid reconnection to the main grid.

Automatic synchronization

Operating principle

When the main network is in a stability condition, the off-grid Microgrid can restore the on-grid operation. For the reconnection process, it is easier to consider the Microgrid as a low voltage generator. For example, the parallel of a running diesel GenSet to the grid is exactly the same as for the active Microgrid:

- the synchronisation process aligns the generator voltages and frequency with the reference values, in particular the distribution network ones.
- when suitable synchronism conditions about voltage and frequency are met, the generator is connected in parallel with the grid.

From the system point of view, the Microgrid reconnection is challenging as it is centralized in the unique point of the interface between the main grid and it involves a lot of resources, not only a machine. Due to this consideration, plant automatization is needed in addition to local generator control.

Emax 2 uses integrated logics and works as a central controller for the main generators to support the Microgrid synchronization. Once the required synchronism is achieved, Emax 2 realizes the automatic connection of the Microgrid through Ekip Synchrocheck module.

Emax 2

Synchro Reclosing

The Distribution System Operators (DSO) have defined tolerance ranges for amplitude, frequency and phase shift parallel conditions for generators, which can be extended to the Microgrid case (see Table 1). Interconnection is allowed if the low voltage Microgrid electrical parameters are within the following operational ranges:

- $\Delta V = V_{grid} - V_{Microgrid}$, difference of voltage magnitude between main grid and Microgrid, express as percentage of nominal voltage U_n (for example, 400V);
- $\Delta f = f_{grid} - f_{Microgrid}$, difference of frequency between main grid and Microgrid, express in Hz;
- $\Delta \varphi = \varphi_{grid} - \varphi_{Microgrid}$, difference of frequency between main grid and Microgrid, express in degrees.

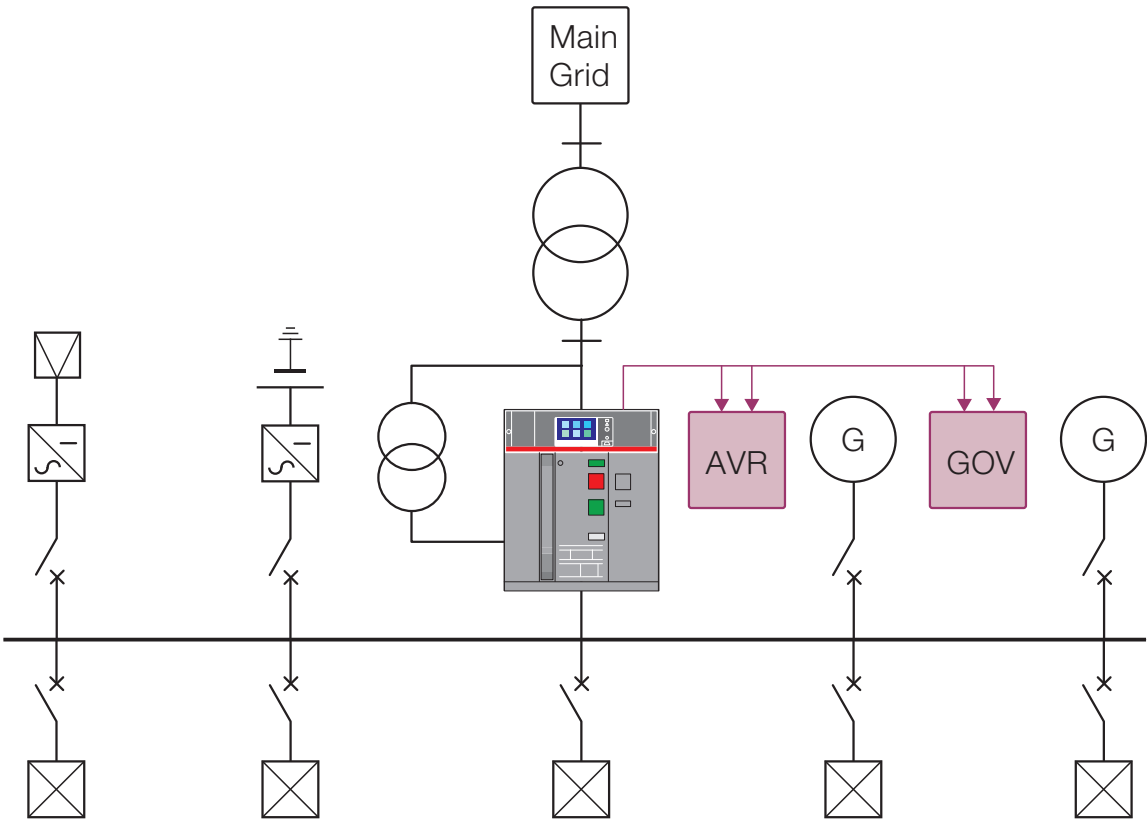
Table 1: example of Italian standard value for active source reconnection to the main grid

Microgrid Size	ΔV	Δf	$\Delta \varphi$
< 400 kW	±10 %	±0,5 %	±10°
> 400 kW	±15 %	± 0,5 %	±10°

Measuring voltage and frequency both upstream and downstream, Emax 2 is able to read and decide how to proceed to get the Microgrid closer to the synchronism band. The on-board logics compare the values measured on the two grid sides and produce digital outputs sent to the control system of the biggest synchronous generators of the Microgrid. This procedure can be automatically realized when Emax 2 is open or activated by an input sent to the circuit breaker, which starts the synchronization and deactivates when the synchronism is detected.

For example, if the Microgrid voltage is lower than the grid one, Emax 2 sends a command to the automatic voltage regulator (AVR) of a GenSet in order to increase - or decrease - the voltage excitation. Besides, if the Microgrid frequency is lower than the grid frequency, Emax 2 sends a command to the GenSet governor of speed (GOV) to increase - or reduce - the machine speed. This operational concept is illustrated in Figure 6

Figure 6: Emax 2 for Microgrid synchronization



Control logic

When the main circuit breaker at the interface point is open, the Microgrid continues its operation in an islanding mode, in this particular operating condition the generators in the Microgrid are likely to reach a steady state characterized by a frequency and voltage difference from the nominal values of the distribution-grid.

As said, before reclosing the Microgrid, some requirements on voltage and frequency have to be satisfied, according to the local Standard (e.g. Table 1 for the Italian Std. CEI 0-16). Therefore, voltage and frequency must be adjusted to synchronize the Microgrid with the operating conditions of the distribution grid. In order to achieve this result, an external retroaction loop is introduced to change reference values of the primary control loops present in the GOV and AVR.

This control is purely proportional and modifies the set point of the GOV and the AVR. In particular, the voltage and frequency are measured upstream and downstream of the interface circuit breaker. Then, the difference is computed and, accordingly to the sign of such difference, the reference value for voltage and current is changed accordingly by a fixed step, as described in Figura 7, Figura 8.

Figure 7: control logics embedded in Emax 2

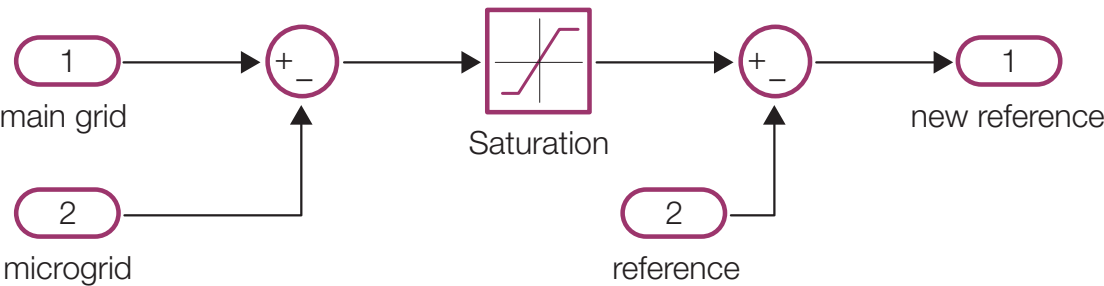
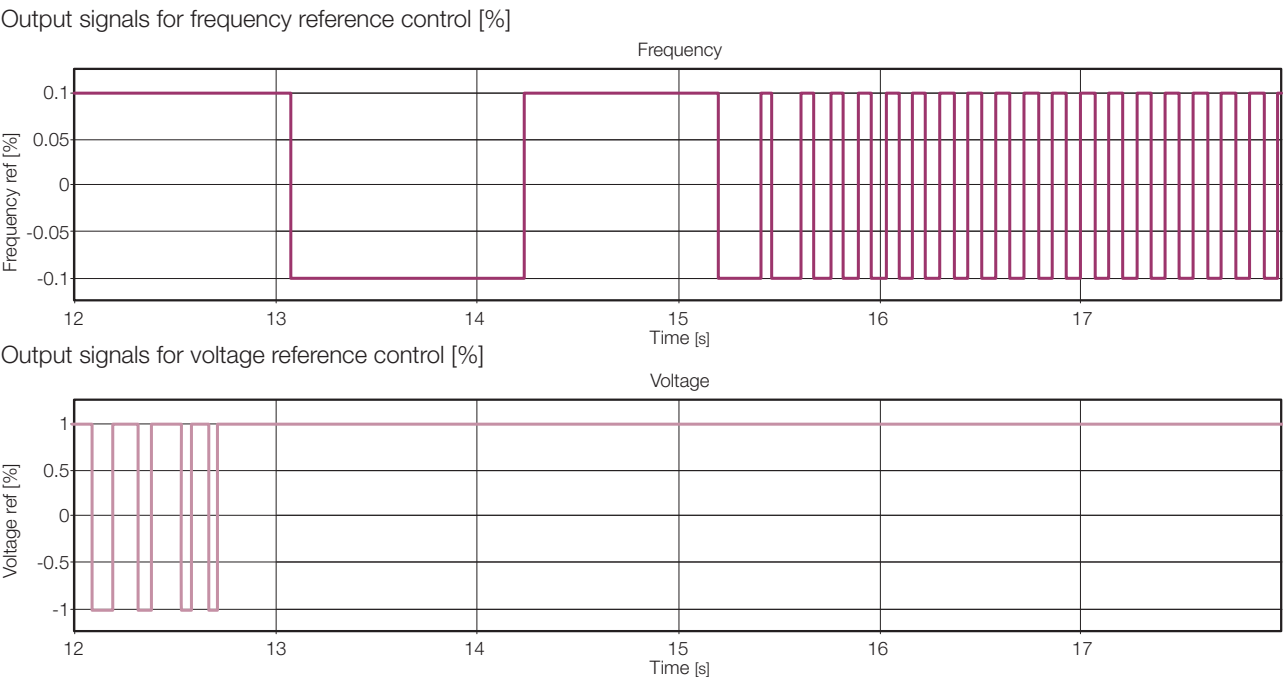


Figure 8 example of the voltage and frequency reference control from Emax 2.



Emax 2

Synchro Reclosing

Ekip Connect 3.0 commissioning tool

Synchronization logics can be easily programmed thanks to a predefined template, ensuring a simplified approach in the commissioning software, Ekip Connect 3.0. It is possible to make practice and get familiar with Synchro Reclosing also before purchasing the SW license and transfer the logics to the circuit breaker. Besides, even after the circuit breaker has been installed in the switchgear, the upload of this function is available. It is also possible to save projects in dedicated files and upload them for “twin plants”.

Figure 9 describes the Synchro Reclosing commissioning start. The synchronization phase programming is realized in just one step described in Figure 10.

Figure 9

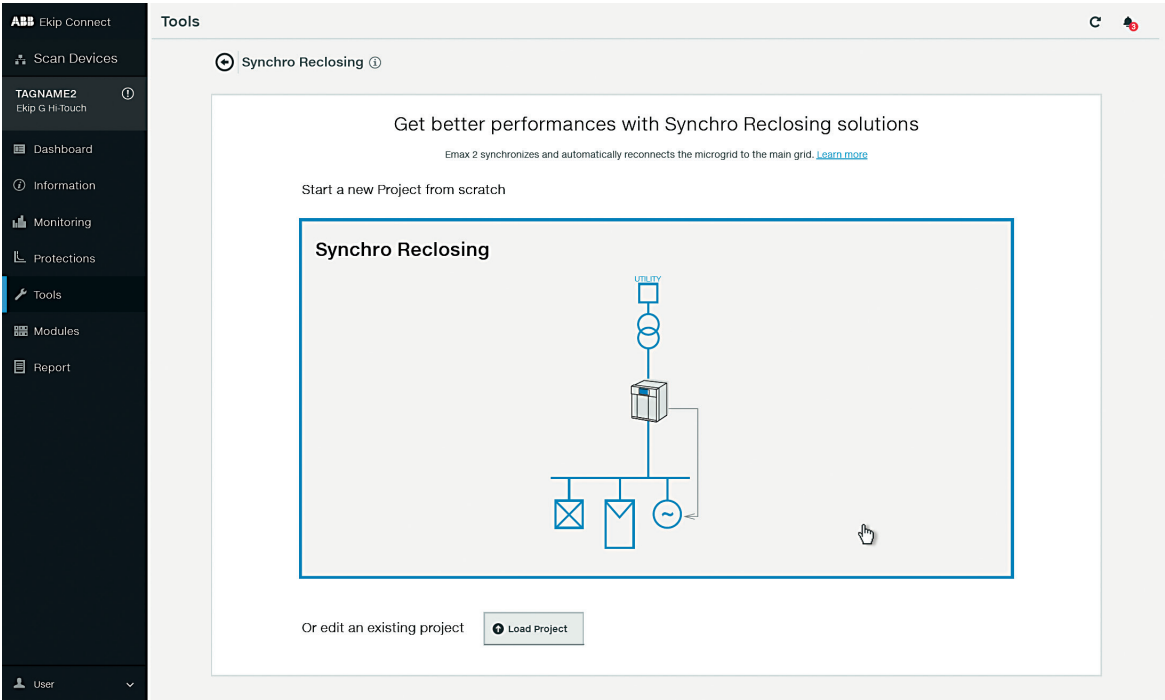
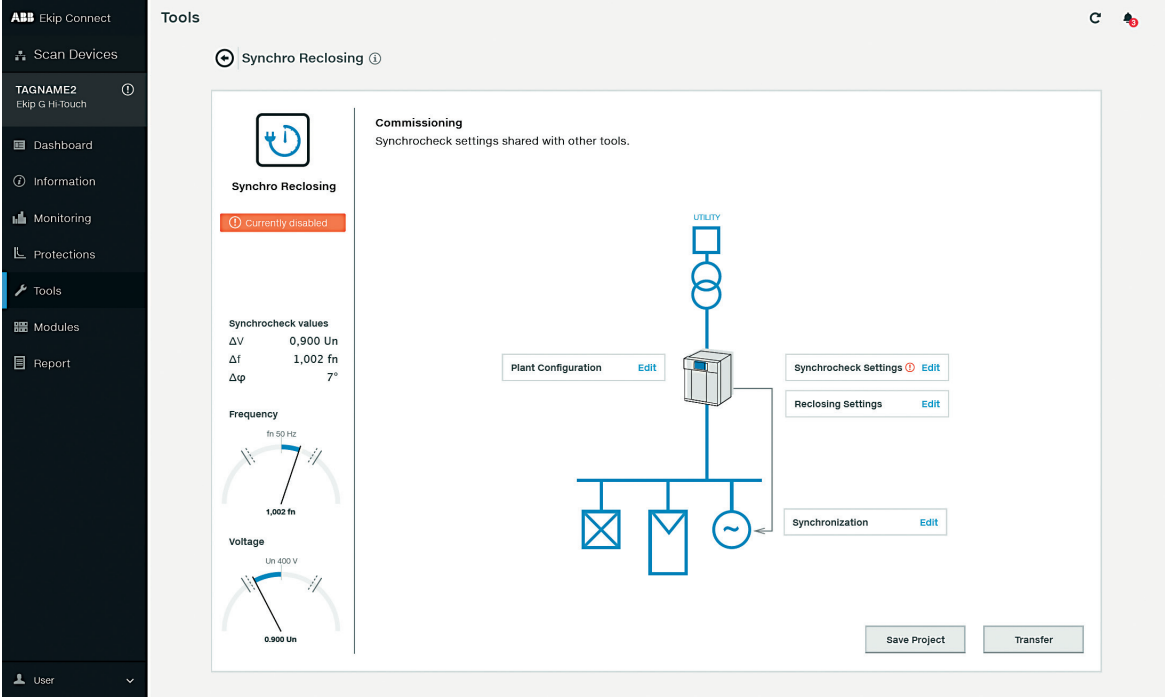


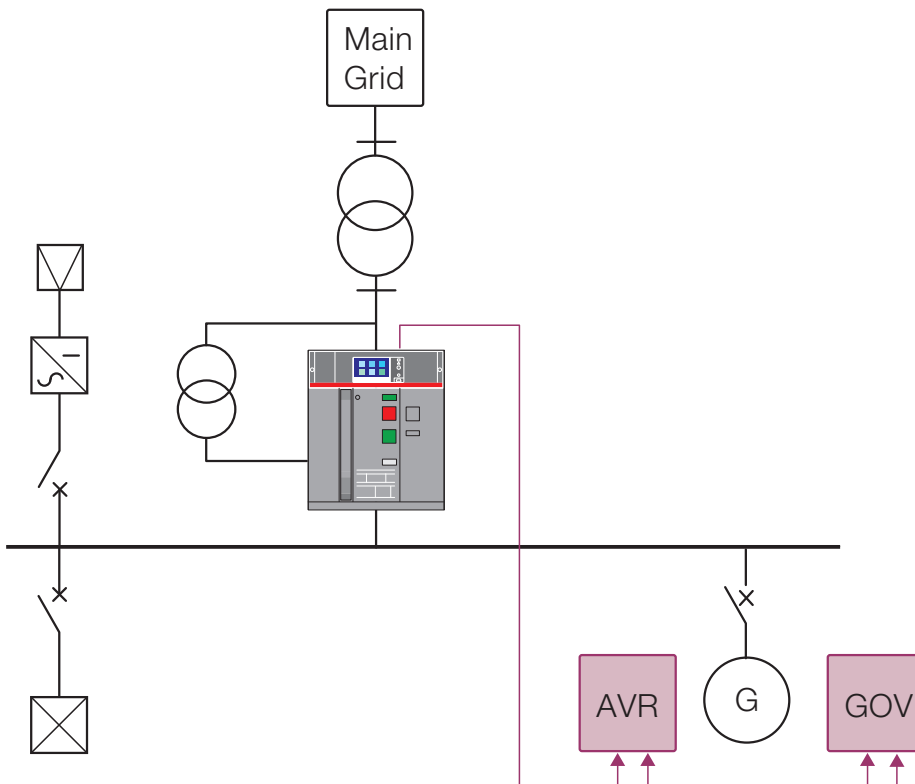
Figure 10



Application example

The Microgrid considered is the same as shown in Figure 12: a low voltage plant with a 450kVA GenSet, a load of the same size and a solar plant connected by a 400kVA transformer.

Figure 11: Microgrid example



The Microgrid is connected to the LV (low voltage) side of the distribution-grid by means of the Emax 2 characterized by $I_n = 2 \times I_{n_gen} = 1300A$ and then through a LV/MV transformer of 630kVA to the MV (medium voltage) side of the distribution network.

Figure 12 graphically reports the voltage and frequency of the Microgrid in the presence of the external retroaction loop realized by Emax 2.

Emax 2

Synchro Reclosing

The Microgrid starts in an island operation mode, thus, its voltage and frequency are typically different from the medium voltage grid, with values that come from the islanding operation. In the example, the values are 320 V (80% Vn) and 49 Hz (98% Vn). In such situation, the requirements of the distribution system operator prevent the Microgrid from being connected to the main grid.

The ability of Emax 2 to measure frequency and voltage at its ends and support the regulation systems of the synchronous generator solves this issue. In fact, the operating point of the Microgrid is restored close to the distribution network, thus allowing reclosing operation.

Figure 12: example of voltage and frequency synchronization with vales in per unit

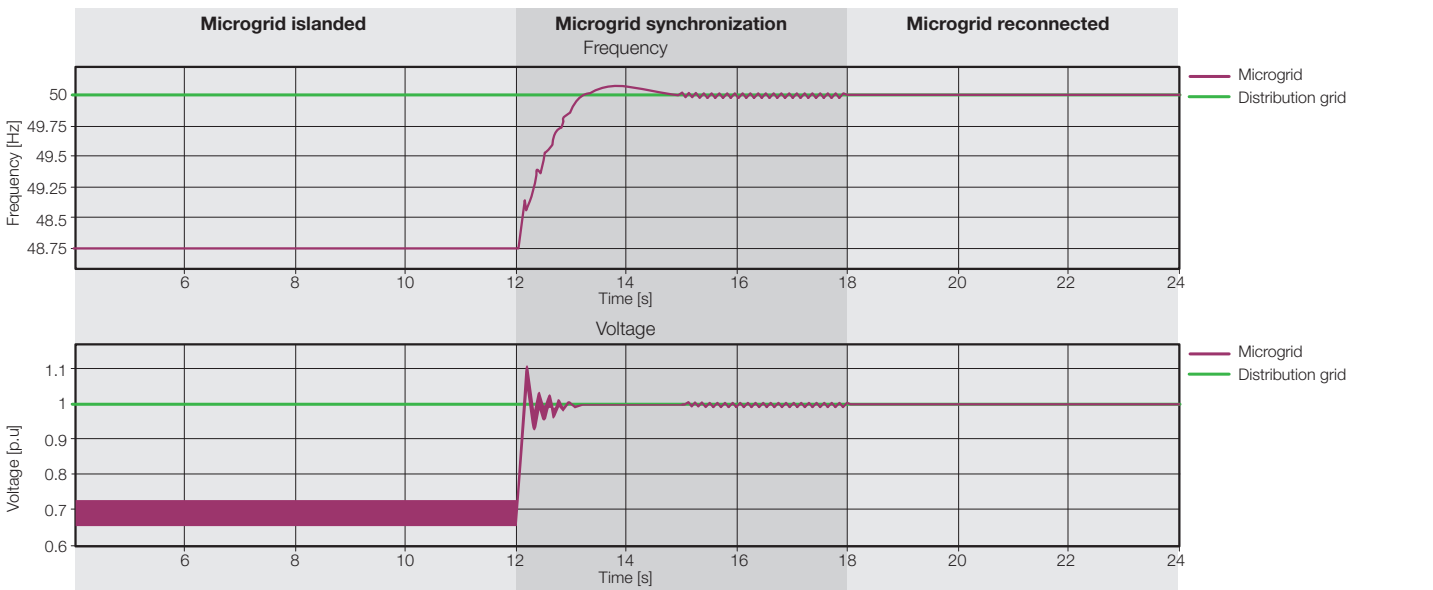
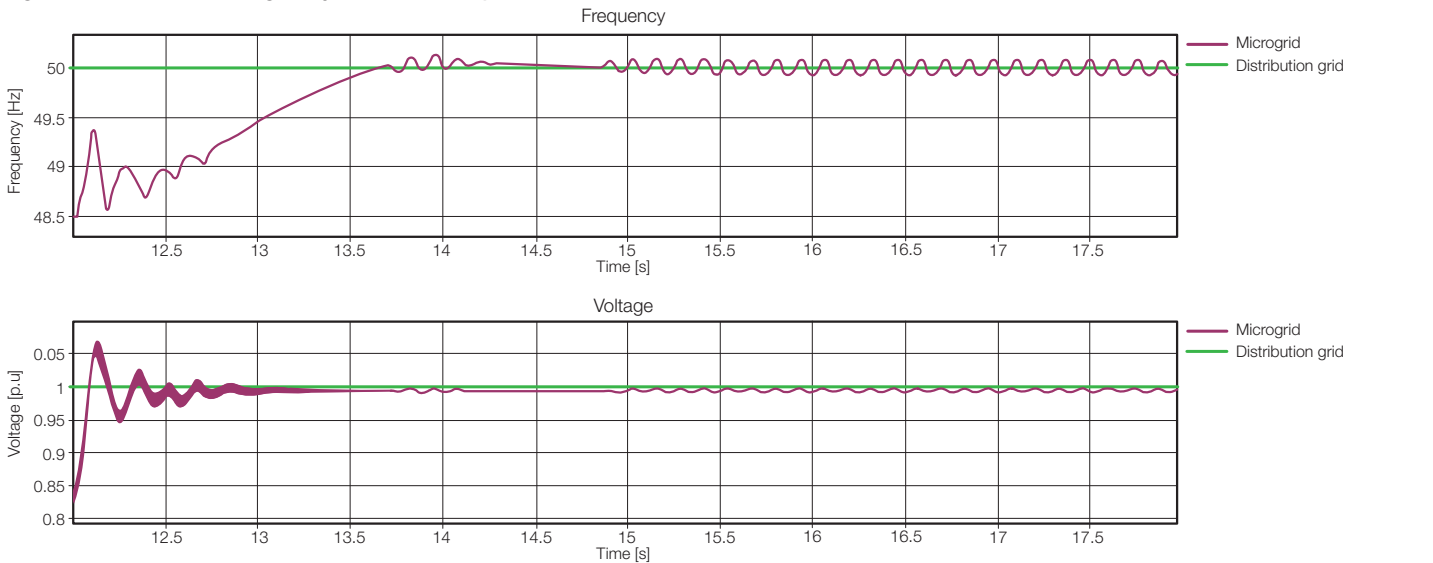


Figure 14: detail of Microgrid synchronization phase

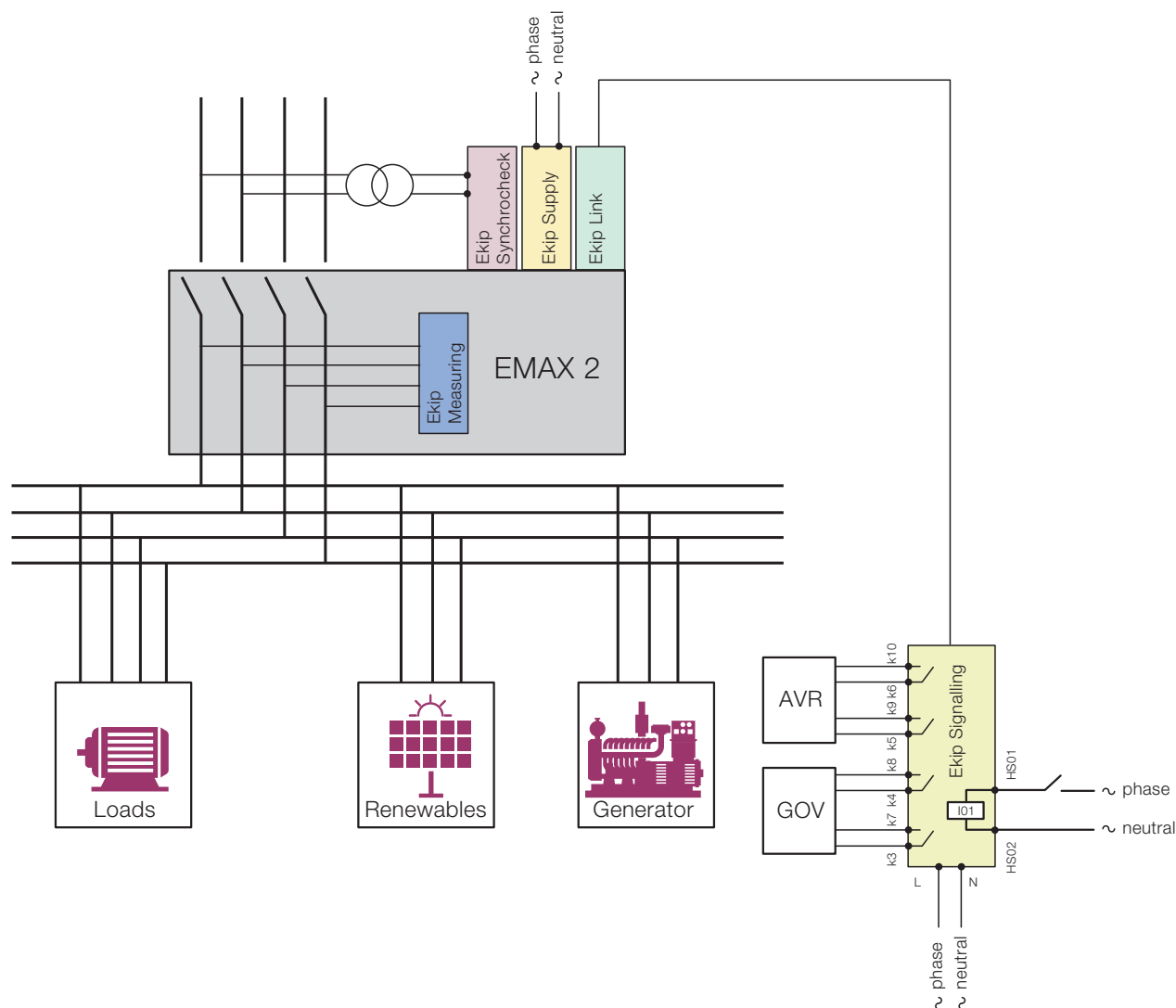


Electrical diagram for automatic synchronization

Ekip Synchrocheck module is wired according to Figure 14. The breaker voltage sockets are positioned at the Microgrid side (downstream), while the single-phase voltage transformer is connected to the main grid side (upstream).

Ekip Signalling output contacts (see Annex B) are connected to the AVR and GOV regulators. In Figure 14, Ekip Singalling 10k is connected to Emax 2 through Ekip Link (see Annex C), on an Ethernet cable. Ekip Signalling 4k can be used instead when the generator is near the switchgear housing Emax 2.

Figure 14: example of electrical diagram for Microgrid synchronization



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Synchro Reclosing

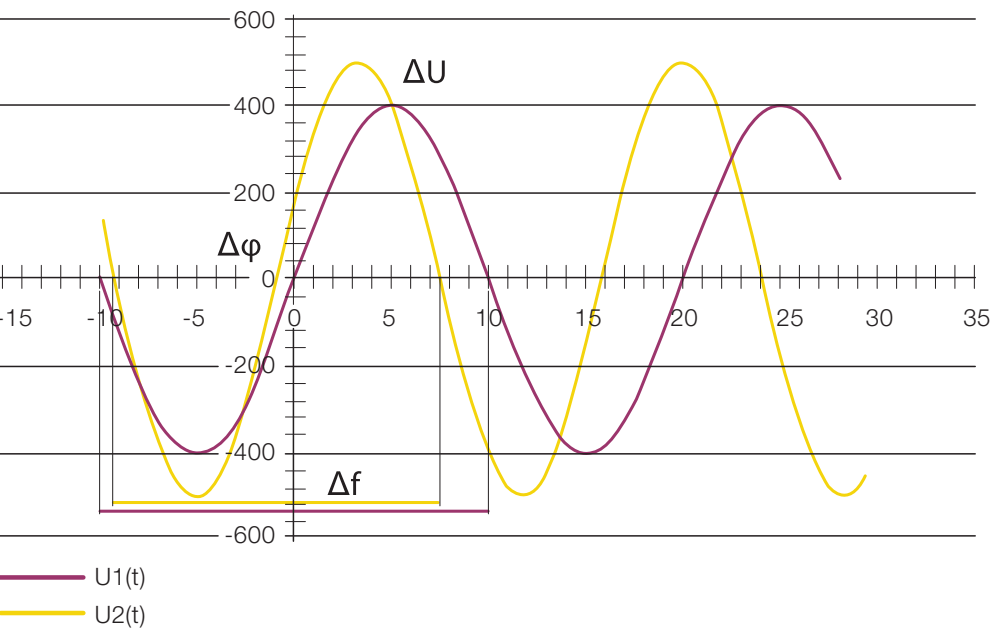
Automatic reclosing

Operating principle

The key parameters to limit the current peaks during the parallel transient are the phase displacement and voltage magnitude difference between the Microgrid and the distribution-grid in a time slot that depends on the frequency difference between the two sources.

Emax 2 embeds ANSI 25 protection, allowing the automatic reclosing only in the presence of a phase, voltage, frequency displacement that is lower than or equal to the ones related to the maximum current transient admissible at the critical condition.

Figure 15: waveforms for not synchronized sources



The synchronism protection for Microgrid enables the “live busbar” mode of interconnection, which allows the interface circuit breaker reclosing on the energized main grid.

In this mode, Emax 2:

- checks that the main grid is actually stable. If required by the local Standard (e.g. Table 2), the main grid voltage and frequency should be within the specified range for a defined time interval;

Table 2. example of stability conditions requested by Italian CEI 0-16 standard

Range	Default Settings
$90\% U_n < U_{\text{main grid}} < 110\% U_n$	30s
$99,5\% < f_{\text{main grid}} < 100,5\% f_n$	30s

- checks the synchronism condition by monitoring the persistence of the difference of that voltage ΔV , frequency Δf and phase-angle $\Delta \varphi$ between the Microgrid and the main grid are within the range for the defined time interval, t_{syn} . The parameters must be set based on the Microgrid configuration. Ekip Connect provides some setting parameters by default (see further details in 4.2.2);
- verifies that the circuit breaker is in open position.

Once the above conditions have been verified, Emax 2 recloses by sending a command to its closing coil through Ekip Signalling.

Ekip Connect 3.0 commissioning tool

Automatic reclosing function is easily configured thanks to Ekip Connect 3.0 commissioning software, which gives useful indications on the critical values, ΔV , Δf , $\Delta \phi$, t_{syn} , during the design of the Microgrid.

The software is fully customizable and allows the user to insert the actual data of the Microgrid elements in the “Plant Configuration” wizard (Error! Reference source not found.) to get advice for the main “Synchrocheck Settings” (Figure 18). The “Plant Configuration” has some “Specialist Parameters” that can be edited by expert users; otherwise, default values are available in the template.

Figure 16:: Plant Configuration for Synchro Reclosing commissioning

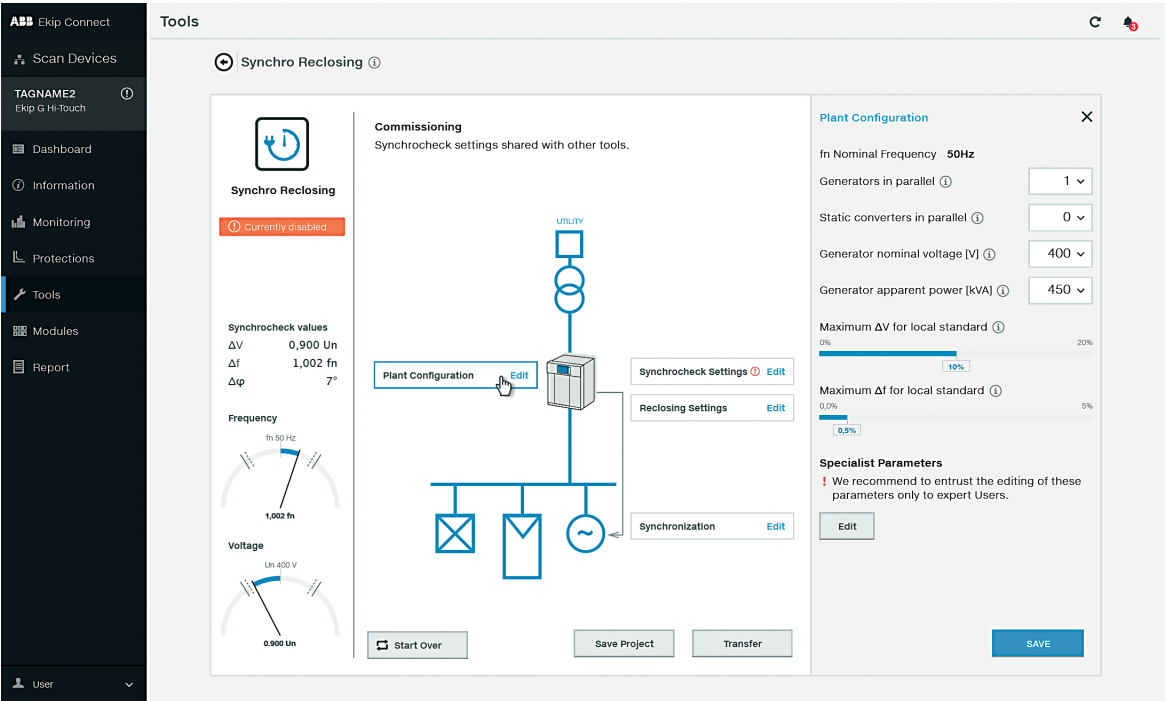
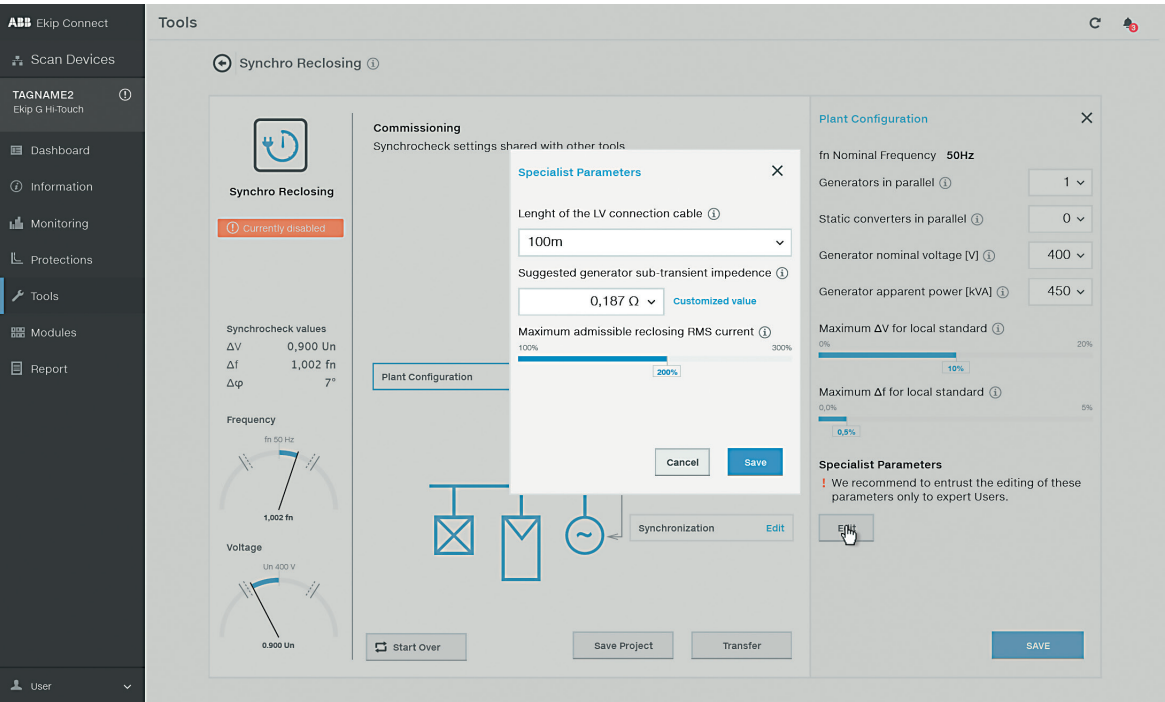


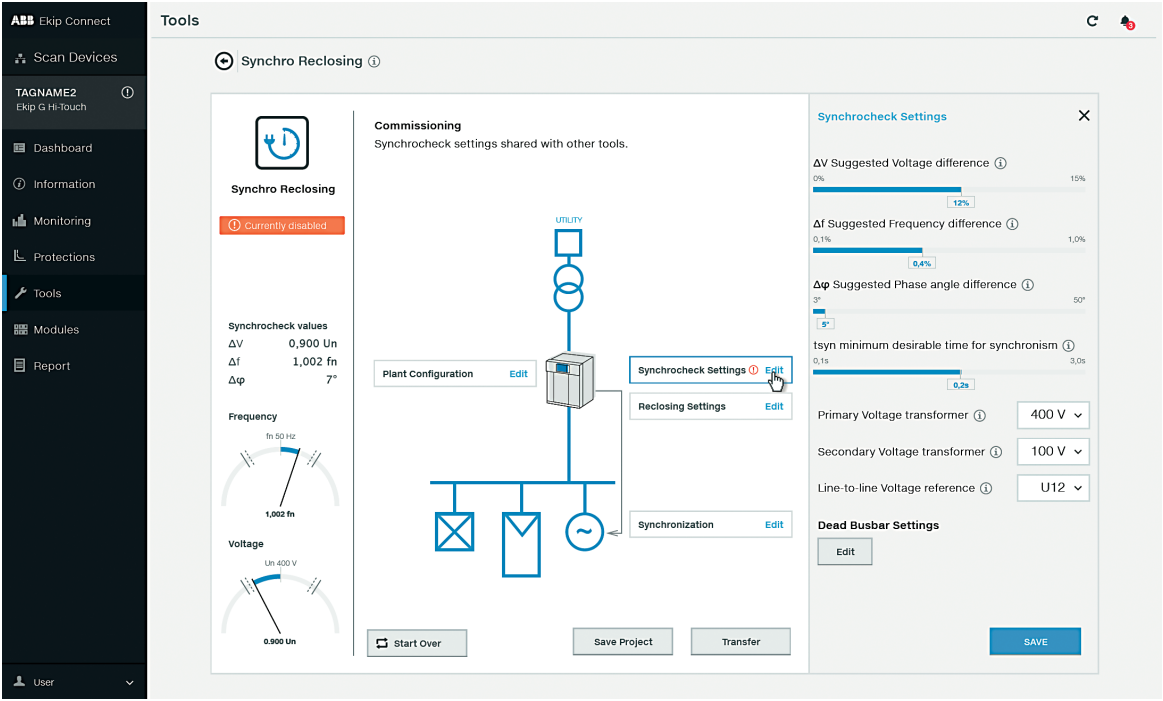
Figure 17: specialist parameters for Plant Configuration



Emax 2

Synchro Reclosing

Figure 18: Synchrocheck Settings for Synchro Reclosing commissioning



The last part of commissioning is related to the “Reclosing Contact” phase. It defines the contact that recloses Emax 2 after the synchronism identification (Figure 19). Then, it is possible to transfer the purchased logics to the circuit breaker and enable the Synchro Reclosing. It is possible to disable it any time by clicking on the dedicated button.

Figure 19: Reclosing Contact for Synchro Reclosing commissioning

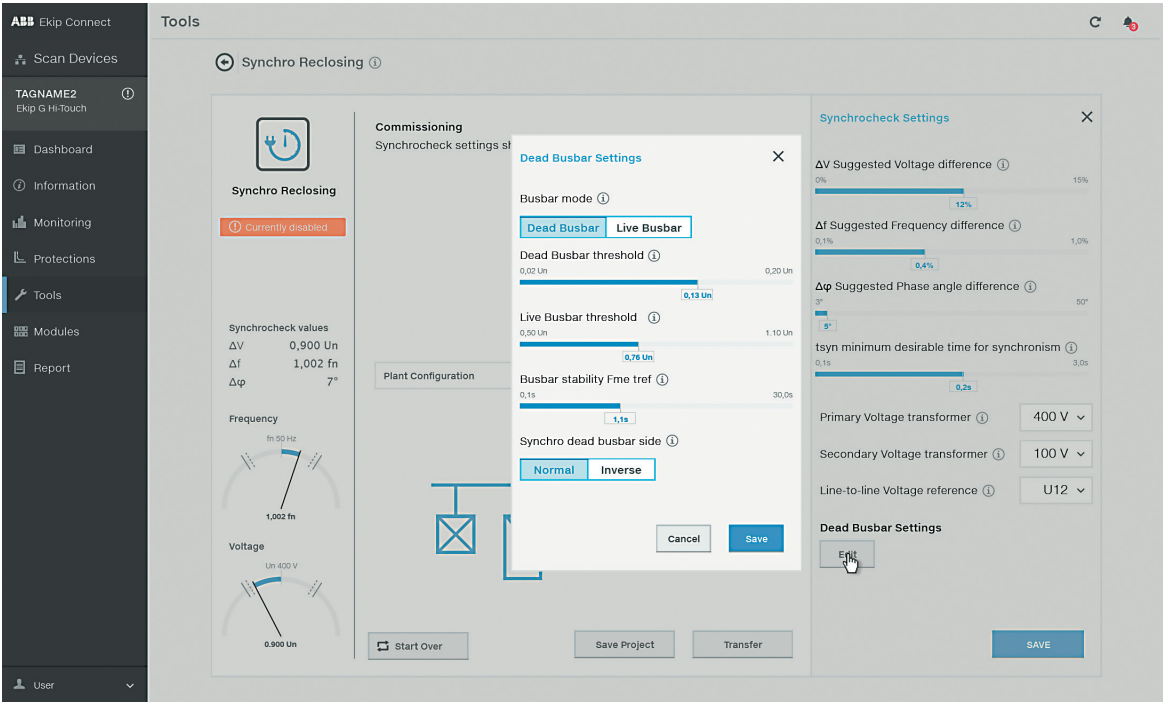
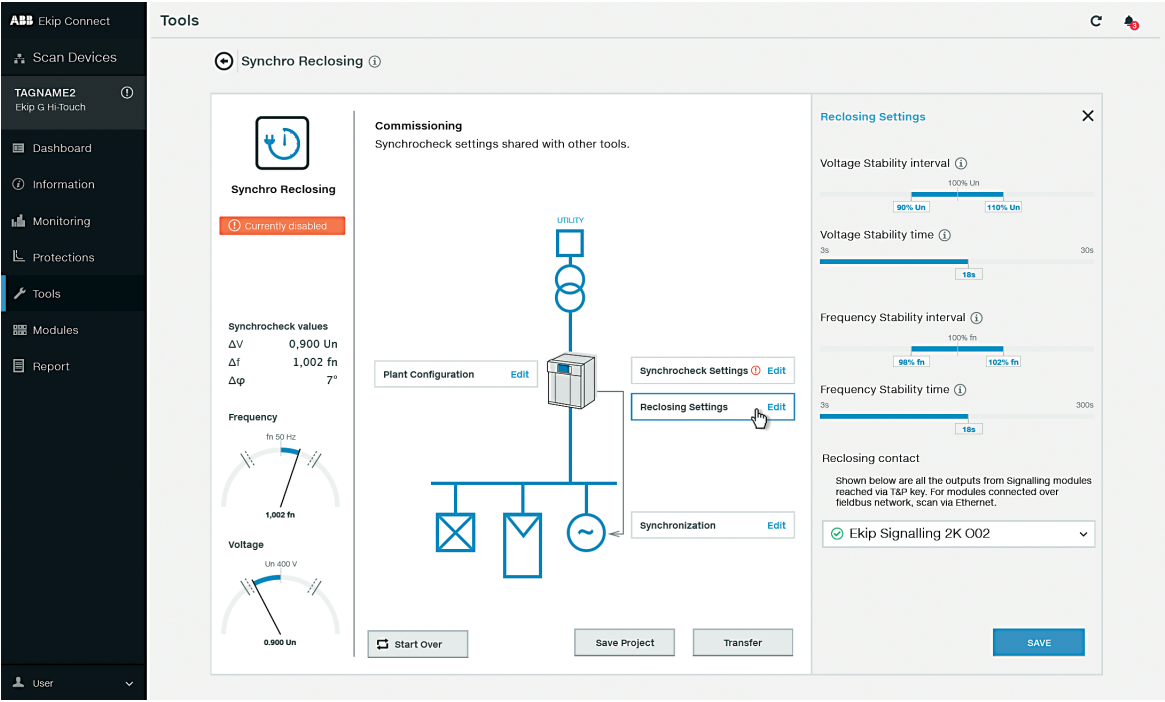
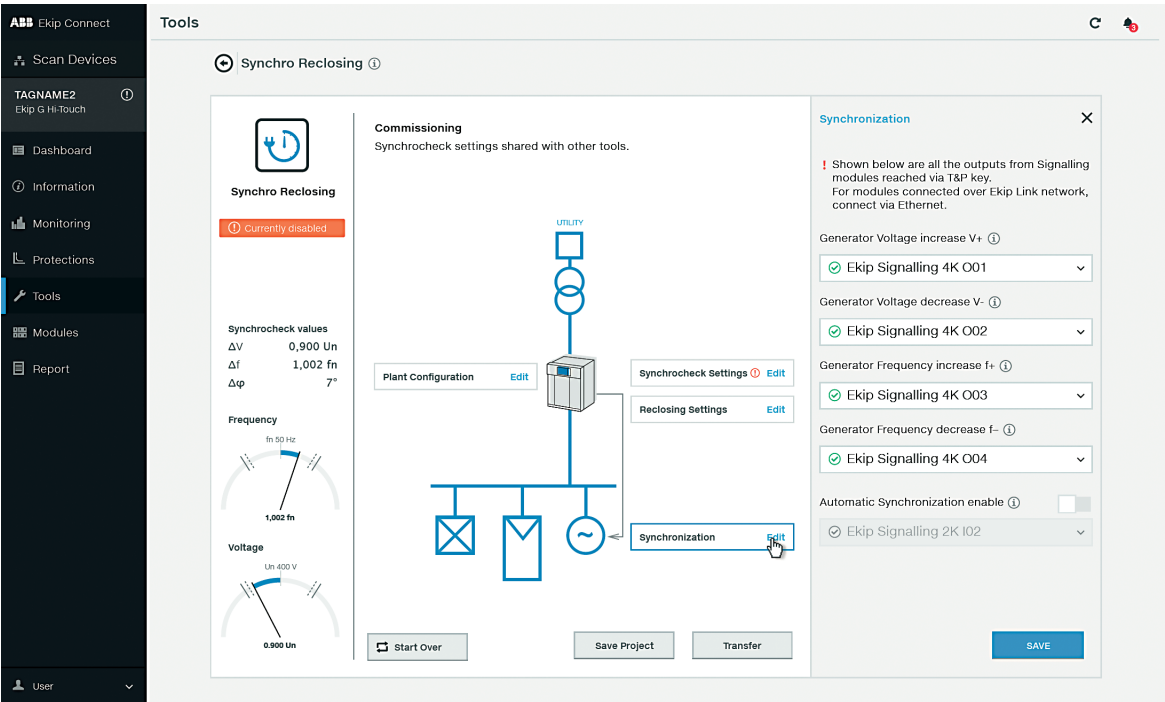


Figure 20: logic transfer to Emax 2⁴



⁴ Synchro Reclosing is not suitable with IPS (see White Paper 1SDC007117G0201 - Interface Protection System and Interface Device).

Figure 21: Synchro Reclosing enabled



Emax 2

Synchro Reclosing

Sensitivity analysis

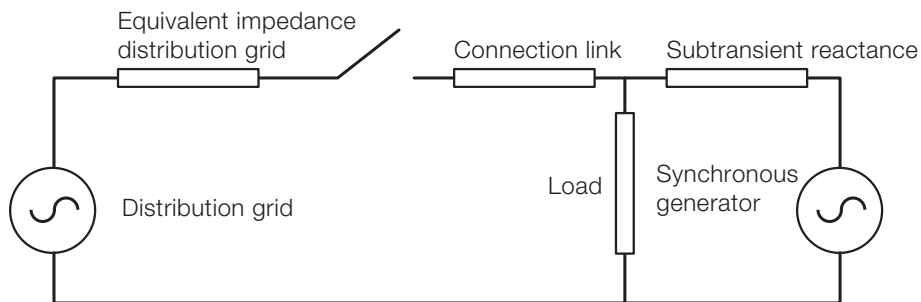
It is typical not to know all the information required for active plant synchronization. Based on the effective easy-to-use purpose, Ekip Connect suggests the most significant parameters in the "Plant Configuration" template (see 4.2.2) that is based on a benchmark model. It does not replace specific engineering projects, but it simplifies the settings choice of the consultants.

- The main grid is represented by a voltage generator plus and equivalent impedance, Z_{grid} . In this case, also the substation transformer is considered.
- The connection link is modelled as an RL branch and represents the cable that links the interface breaker with the Microgrid, Z_{line} .
- The Microgrid is modelled as a synchronous generator, an ideal voltage source with an impedance in series that for this application is considered equal to the sub-transient impedance with a parallel-connected load, $Z_{generator}$ and Z_{load} .

The current flowing in the interface breaker is:

$$I_{breaker} = \frac{V_{grid} - V_{microgrid}}{(Z_{generator} // Z_{load}) + Z_{grid} + Z_{line}}$$

Figure 22: Microgrid model for the SW tool

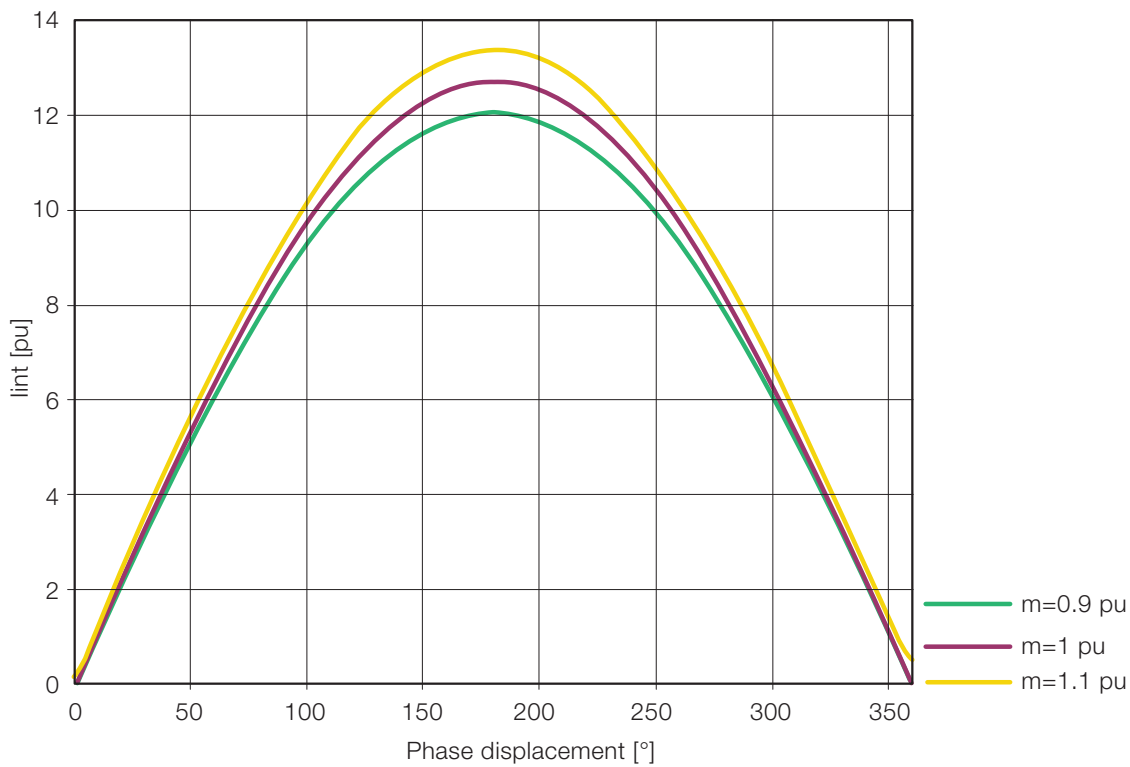


The default settings given by Ekip Connect have been defined starting from a simplified model that is the result of a sensitivity analysis related to all the elements present in Figure 22

Sensitivity with respect to the Microgrid voltage

Figure 23 shows the transient current during the reclosing phase, as per unit of circuit breaker nominal current, with reference to different Microgrid voltage values, as per unit of main grid voltage, within a range that is required by local Standards for Microgrid reconnection.

Figure 23: Sensitivity with respect to Microgrid voltage



The absolute value of ΔV , where $\Delta V = V_{\text{grid}} - V_{\text{Microgrid}}$, has its maximum when the phase displacement between the two voltage waveforms is 180° . With a phase displacement lower than 40° , ΔV is likely to be the same for different values of $V_{\text{Microgrid}}$. Stated that the reclose is carried out with phase displacements lower than 40° , we can assume that ΔV variable is negligible.

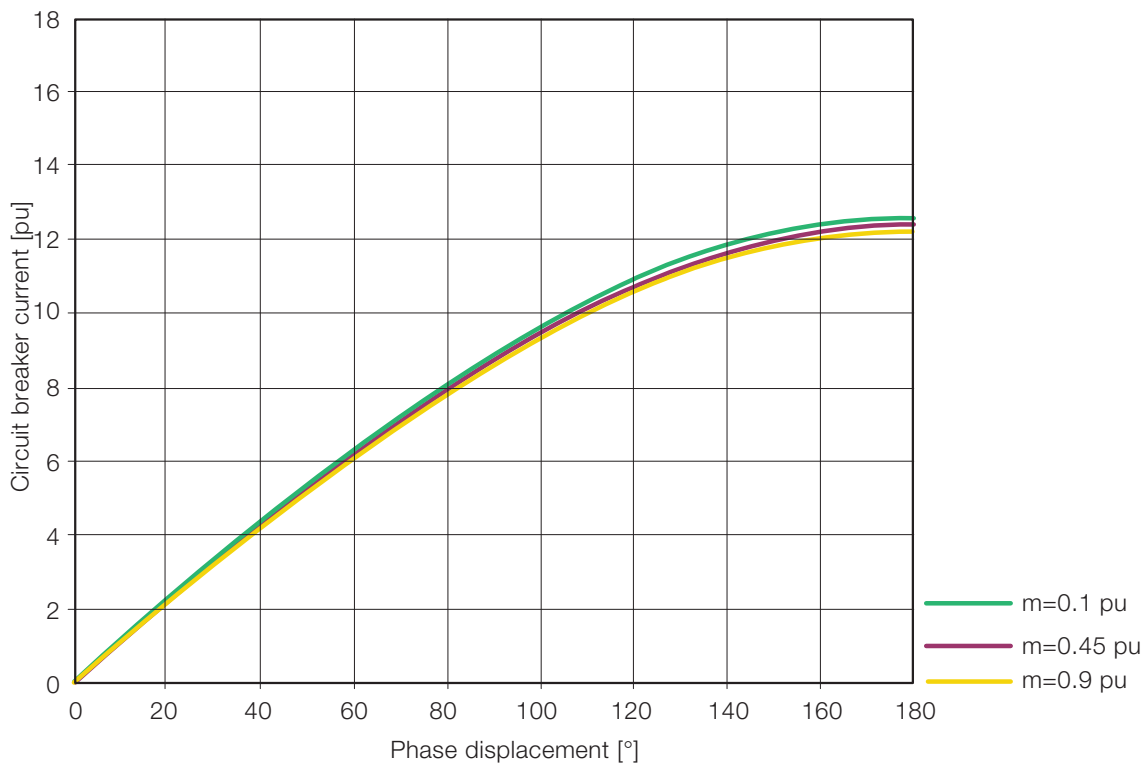
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Sensitivity with respect to the load

Figure 24 shows the transient current during the reclosing phase with reference to different Microgrid loads evaluated as per unit values of the Microgrid generator size.

Figure 24: Sensitivity with respect to Microgrid electrical load

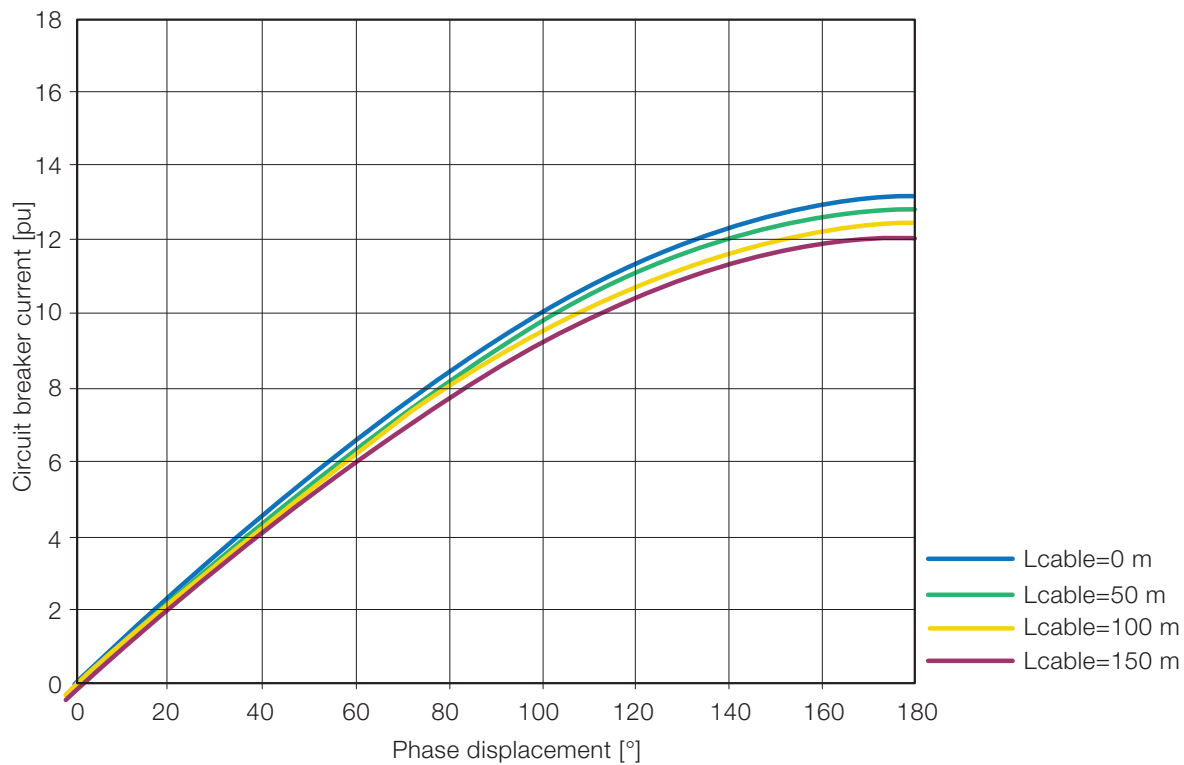


The transient due to the reclosing operation is characterized by a fast dynamic; therefore, the equivalent impedance of the generator is the sub-transient reactance of the generator, which is very small if compared with the impedance of the load that is electrically in parallel. Based on this, it can be assumed that the different load sizes are likely to have a minimum influence over the peak value of the current during the transient.

Sensitivity with respect to the connection link

Figure 25 shows the transient current during the reclosing phase with reference to different lengths of the connection link between the interface circuit breaker and the Microgrid generator.

Figure 25: Sensitivity with respect to connection link between the interface circuit breaker and the Microgrid generator



The length of the connection link proves not to be a critical parameter for phase displacement within 40°, so it does not influence the peak of the current in a critical way.

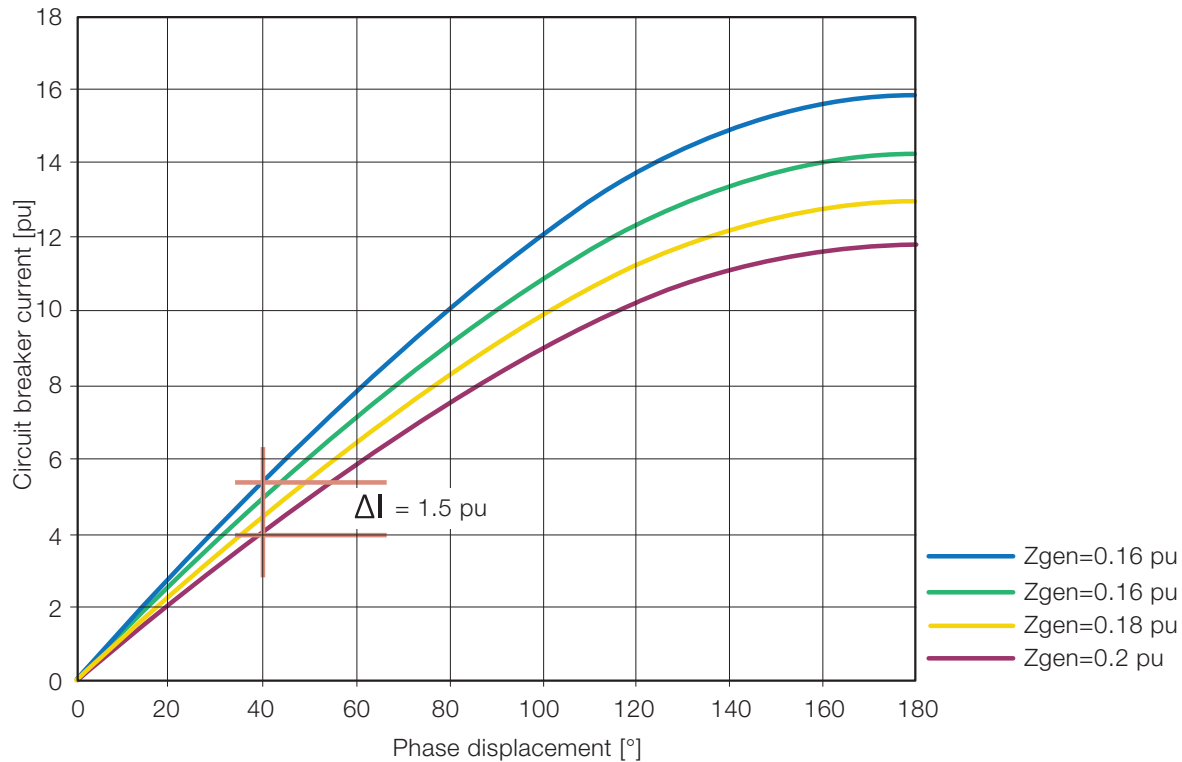
Emax 2

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Sensitivity with respect to the sub-transient impedance of the generator

Figure 26 shows the behavior of the current during the transient reclosing phase, with reference to the dynamic impedance values of the Microgrid generator.

Figure 26: Sensitivity with respect to Microgrid generator sub-transient impedance value



The current flowing in the interface breaker is not an issue with respect to the size of the synchronous generators because of the proportionality among the elements of the Microgrid.

On the other hand, if different values of the sub-transient impedance are considered, then different values for the current can be found: at 40° with a difference in the sub-transient impedance of 0.06 p.u. there is a difference in the current of 1.5 p.u.

To summarize, the great difference among the impedance of the synchronous generators, the line impedance and the grid parameters allows us to simplify the customer data necessary to find the maximum phase for admissible reclosing: impedance of the generator is the element that mostly influences the critical values for reclosing.

SW tool hypothesis

Based on the above sensitivity considerations, the following parameters has been assumed in the software tool.

For the default MV/LV transformer:

An=630kVA
V1n=20kV
V2n=400V
vcc=4%

For the default distribution network:

Acc=1000MVA
V=20kV

- The default LV cable is characterized by a 100m length and nominal current equal to 1.1 times the nominal current of the generator, with the following per unit length resistance and reactance values:
 $r = 0.642 \Omega/\text{km}$
 $x = 0.083 \Omega/\text{km}$.
- The static converters are characterized by two different impedances for the calculation of the contributions to the reclosing current depending on how they are connected, for example whether a connection transformer is present or not⁵.
- The static converters are considered for the equivalent impedance seen by the circuit breaker during the reclosing operation. Indeed the tool identifies the smallest Microgrid impedance and divides it by the number of generation devices in parallel. In this way, the calculation of the current flowing in the circuit breaker during the reclosing transient is conservative. On the other hand, in order to analyze the current value that involves the generators, the static converters are expected to be disconnected after the stressing dynamic transition for their built-in protection sensitivity. Based on this consideration, for the assumption to set the maximum current on the interface circuit breaker as the same one of the generators, which should not trip during the Microgrid reconnection, the following conditions must be verified:

- If there are two generators in the Microgrid

$$\begin{cases} k_{gen} I_{n_a} \geq \frac{1}{2} k_{int} (I_{n_a} + I_{n_b}) \\ k_{gen} I_{n_b} \geq \frac{1}{2} k_{int} (I_{n_a} + I_{n_b}) \end{cases}$$

- If there are three generators in the Microgrid

$$\begin{cases} k_{gen} I_{n_a} \geq \frac{1}{3} k_{int} (I_{n_a} + I_{n_b} + I_{n_c}) \\ k_{gen} I_{n_b} \geq \frac{1}{3} k_{int} (I_{n_a} + I_{n_b} + I_{n_c}) \\ k_{gen} I_{n_c} \geq \frac{1}{3} k_{int} (I_{n_a} + I_{n_b} + I_{n_c}) \end{cases}$$

Where k_{gen} is the maximum admissible current level with respect to the nominal one to avoid the tripping of the protection of the generator (e.g. selectivity short-circuit protection), while k_{int} is the same as k_{In} that is the maximum admissible circuit breaker reclosing current.

⁵ The static converters, if present, are assumed to be connected to the Microgrid by a transformer as default choice. This parameter can be set during the "Plant Configuration" commissioning phase, considering all the static converters connected with or without a transformer.

Emax 2

Synchro Reclosing

Table 3 shows an example of the possible GenSet sizes that respect the above constraints.

Table 3: generator size example in compliance with the SW tool

	Coefficient protection [generator/circuit-breaker]	Nominal power generators [generator A,B,C]		Nominal current generators [generator A,B,C]		Nominal current circuit-breaker, maximum current circuit breaker		Maximum current for generator protection		Actual maximum current in generators	
		AnA [kVA]		InA [A]		$InCB$ [A]		$InAmax$ [A]		$InAmax$ [A]	
K_{gen}	3	AnA [kVA]	400	InA [A]	600	$InCB$ [A]	1800	$InAmax$ [A]	1800	$InAmax$ [A]	1800
K_{int}	2	AnB [kVA]	810	InB [A]	600	$ImaxCB$ [A]	1800	$InBmax$ [A]	3600	$InBmax$ [A]	1800
K_{gen}	3	AnA [kVA]	400	InA [A]	600	$InCB$ [A]	2600	$InAmax$ [A]		$InAmax$ [A]	1733.3
K_{int}	2	AnB [kVA]	810	InB [A]	1200	$ImaxCB$ [A]	5200	$InBmax$ [A]		$InBmax$ [A]	1733.3
		AnC [kVA]	545	InC [A]	800			$InCmax$ [A]		$InCmax$ [A]	1733.3

- The software tool analyses the peak value of the transient current, even if the generator protections work typically with delays for selectivity reasons. This proves to be a conservative approach as the calculated peak is likely to decrease at a rate directly dependent on the dynamic of the system itself. Therefore, the peak value of the reclosing current will be lower than the critical one, as it does not decrease for the entire period considered.
- The defined delay between the command of reclosing and the actual reclosing is 100ms, conservative value for mechanical circuit breakers. This means that the synchronism condition set shall last for at least the defined time interval.

Table 4 summarizes all the parameters required by the SW tool and the default values defined.

Table 4: list of parameters required for the sw tool

Required parameters	Default value
Maximum ΔV is the maximum local standard admissible voltage difference between the grid and the Microgrid at the instant of reclosing.	$\Delta V=10\%$
Nominal frequency is the nominal frequency of the distribution network.	$f=50\text{Hz}$
Maximum Δf is the maximum local standard admissible frequency difference between the grid and the Microgrid at the instant of reclosing	$\Delta f=0.5\%$
The maximum admissible circuit breaker reclosing RMS current, I_{max} , defined by as a multiple of the nominal current of the breaker, such scale factor is defined as: $kIn=I_{max}In$	$kIn=2$
Length of the LV connection cable	$l=100\text{m}$
Number of generators in parallel	Number of active generators = 1
Number of static converters in parallel	Number of static converters = 0
Nominal voltage of the generator [V]	Nominal voltage generator = 400V
Apparent power of the generator [kVA]	Apparent power generator = 175kVA
Sub-transient impedance of the generator [Ω]	Value for ABB generators or set by the user in the "specialistic parameter" window

The main purpose of this Ekip Synchrocheck commissioning software is to give qualitative indications about the critical phase for reclosing the Microgrid, but cannot substitute the standard engineering study, especially in the presence of complex systems.

Application Example

The following examples are related to different configuration of the Microgrid according to the SW tool.

Table 5: example 1

Input for the SW	Output from the SW
ΔV_{\max} for standard definition = 10%	ΔV_{\max} for Emax 2 reclosing = 10%
Δf_{\max} for standard definition = 0.5%	Δf_{\max} for Emax 2 reclosing = 0.4%
f = 50Hz	Maximum reclosing time = 100ms
kint=2	Critical phase for reclosing = 19.7°
Length connection link = 100m	Synchrocheck critical phase for reclosing = 19°
Active generators in the Microgrid = 1	
Static converters in the Microgrid = 0	
Nominal voltage synchronous generator = 400V	
Apparent power synchronous generator = 175kVA	
Sub-transient reactance = 0.2Ω	

Table 6: example 2

Input for the SW	Output from the SW
ΔV_{\max} = 10%	ΔV_{\max} for reclosing = 10%
Δf_{\max} = 0.5%	Δf_{\max} for reclosing = 0.4%
f = 50Hz	Maximum reclosing time = 100ms
kint=2	Critical phase for reclosing = 8.5°
Length connection link = 100m	Synchrocheck critical phase for reclosing = 8°
Active generators in the Microgrid = 1	
Static converters in the Microgrid = 1	
Static converter with connection transformer	
Nominal voltage synchronous generator = 400V	
Apparent power synchronous generator = 175kVA	
Sub-transient reactance = 0.2Ω	

The reclosing operation involves connecting a generator to a live busbar, so the following settings must be made in addition to those enabling the synchronism module (see Annex A):

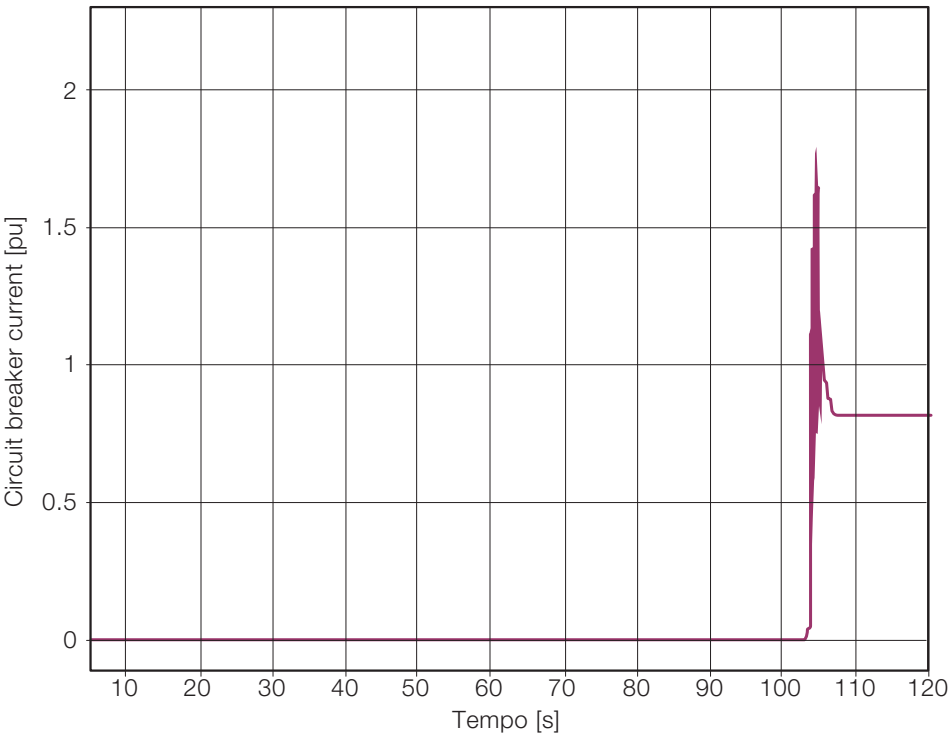
- Selection of reference line-to-line voltage
U12. The selected voltage is taken as a reference for the synchronism check
- VT Primary voltage [V]
according to the network voltage indicated in the initial data, the value 400V shall be set
- VT secondary voltage [V]
according to the secondary voltage of the selected VT (for example 100V), the value 100V shall be set on the trip unit.

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The result is described in Figure 27, where there is the dynamic trend of the current value flowing in the main circuit breaker during the Microgrid reconnection with the above mentioned synchrocheck settings. The current value is showed in per unit of the circuit breaker nominal current.

Figure 27: flowing current in the circuit breaker during the Microgrid reconnection operation



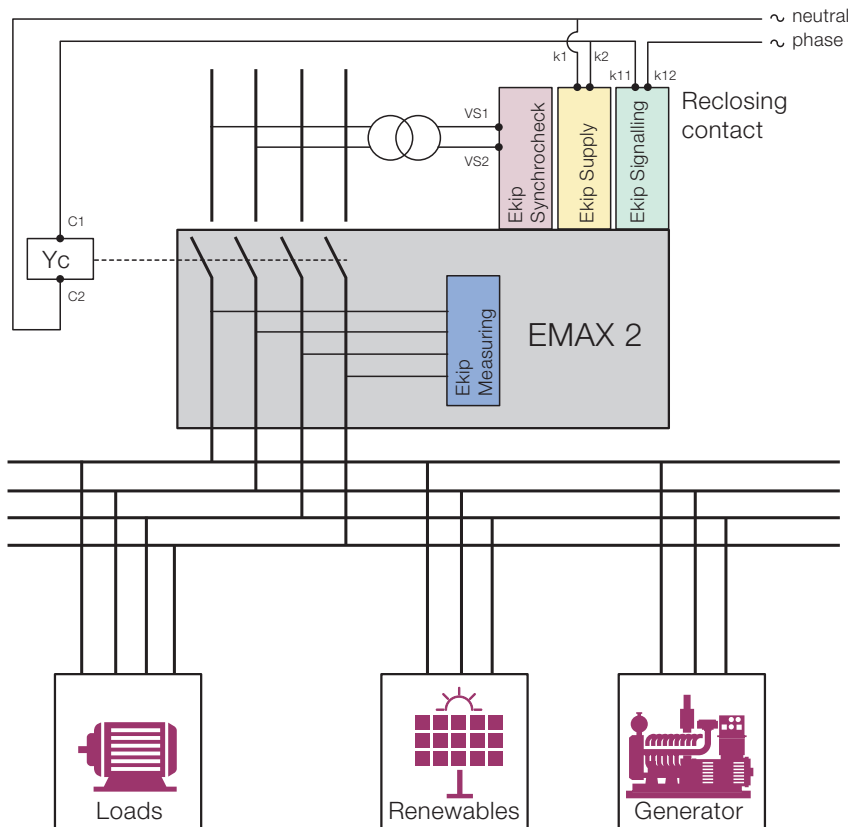
Electrical diagram for automatic reclosing

The connection between the Ekip Synchrocheck module and the protection trip unit is made through the Ekip Supply module, which supplies both the trip unit and the Synchrocheck module.

One Ekip Signalling contact, typically embedded in Emax 2 as in Figure 28, is activated when synchronism and main grid stability is reached. It allows the circuit breaker to be closed directly through wiring with the shunt closing release YC (at 220 Vac⁶).

⁶ For other power supply voltages, an auxiliary power supply unit is recommended.

Figure 28: example of electrical diagram for Microgrid automatic reclosing



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Shopping List

The automatic Synchro Reclosing feature is available with the Emax 2 circuit breaker family equipped with the accessories listed in Table 7.

Table 7:shopping list for Synchro Reclosing

Description	Product	Commercial Codes	Notes ⁷
Trip unit	Ekip Touch trip unit platform + Ekip Measuring Pro	Embedded in Emax 2 circuit breaker	As an alternative, Ekip Hi Touch, Ekip G Touch, Ekip G Hi Touch families
Power supply	Ekip Supply 110-240V AC/DC	Ekip Supply 110-240V AC/DC 1SDA074172R1	As an alternative, Ekip Supply 24-48V DC (1SDA074173R1)
I/O contacts	Ekip Signalling 4k + Ekip Signalling 2K-1	1SDA074170R1 + 1SDA074167R1	As an alternative, Ekip Signalling 10k (1SDA074171R1)+ options for Ekip Link (1SDA074163R1)
Closing coil	YC E1.2..E6.2 220-240V AC/DC	1SDA073687R1	As an alternative, YC closing coil with different power supply voltage
Synchrocheck module	Ekip Synchrocheck	1SDA074183R1	
SW license USB key	Synchro Reclosing	1SDA082923R1	

⁷ For every commercial codes, see 1SDC200023D0204 for IEC and 1SDC200039D0201 for UL.

Annex A – Ekip Synchrocheck

Ekip Synchrocheck module is located in a slot of the accessory area of Emax 2, like the other connectivity modules. For the Synchro Reclosing function, it acquires the voltage between two phases of the line by means of an external single-phase voltage transformer connected at the main grid side and the three line-to-line voltages by means of the Emax 2 internal voltage sockets located at the Microgrid side⁸.

⁸ For Microgrid voltage above 690V, also on the circuit breaker side, a three-phase voltage transformer must be provided and connected to the Emax 2 external sockets on the mainboard.

Figure 29: Ekip Synchrocheck cartridge module



Figure 30: accessory area of Emax 2

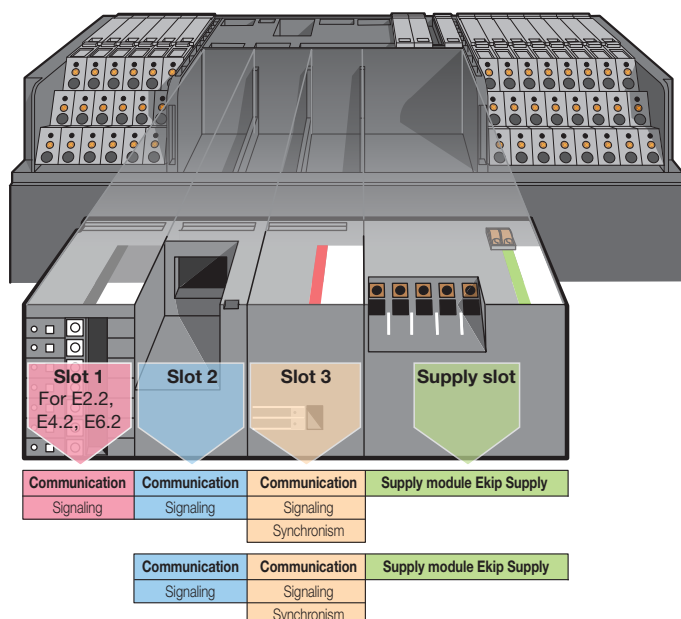


Table 8 lists all the parameters to be set for the Synchro Reclosing. As an extension of this application, it is possible to configure the “dead busbar” operation mode with the values described in Table 9. The electrical diagram is shown in Figure 31.

Table 8: parameters requested for Ekip Synchrocheck

	Maximum admissible difference between voltages to allow the reclosing operation
Δf threshold – frequency difference	range(0.1-1)Hz step 0.1Hz.
	Maximum admissible difference between frequencies to have the reclosing operation
$\Delta \phi$ threshold – phase angle difference	Range (3°-50°) step 1°.
	Maximum admissible phase difference to have the reclosing operation
VT Primary voltage [V]	100,115,120,190,208,220,230,240,277,347,380,400,415,440,480,500,550,600,660,690,910,950,1000,1150V
	Voltage level on the primary windings of the external VT (Synchrocheck module side).
VT Secondary voltage [V]	100,110,115,120V
	Voltage level on the secondary windings of the external VT (Synchrocheck module side).
Selection of reference line-to-line voltage	V12,V23,V31.
	Depending on the connection it is possible to set the reference line voltage (generator side)
Minimum desirable time for synchronism condition t_{syn} (ms)	(0.1-3)s step 0.1s
	The minimum desirable time for synchronism condition defines the available values of Δf and $\Delta \phi$ such that the synchronism condition remains at least for the defined t_{syn} .
	t_{syn} can be calculated by the following relation: $360^\circ \cdot \Delta f \cdot t_{syn} \leq 2 \cdot \Delta \phi$ and it is already suggested as 100ms by the Synchro Reclosing commissioning SW tool.

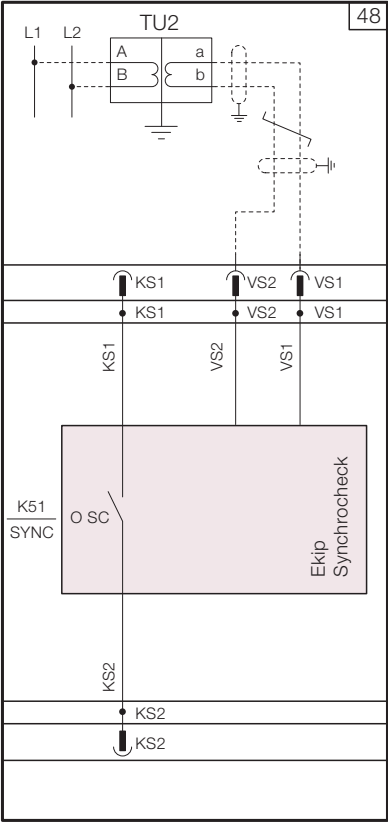
Emax 2

Synchro Reclosing

Table 9: Ekip Synchrocheck parameters for deadb busbar mode

Synchrocheck module enabled	<p>YES/NO.</p> <p>Enables the Synchrocheck module</p>
Dead busbar option	Select operation mode i.e. “live busbar” (select NO) or “dead busbar” (select YES) mode
Live busbar threshold voltage V_{live}	<p>range (0.5-1.1)xVn step of 0.01xVn.</p> <p>The voltage of the system where the module is to be reconnected shall be greater than the live busbar threshold voltage.</p> <p>Such condition has to be satisfied for t_{ref}.</p>
Dead busbar threshold voltage V_{dead}	<p>range (0.02-0.2)xVn step of 0.01xVn.</p> <p>The voltage of the system where the module has to be reconnected must be lower than the dead busbar threshold voltage.</p> <p>Such condition has to be satisfied for t_{ref}.</p>
Busbar stability time t_{ref}	<p>range (0.1 -30)s step 0.1s</p> <p>Time the control voltage has to remain on the live busbar (Live busbar threshold voltage V_{live}) or dead busbar (Dead busbar threshold voltage V_{dead})</p>
Set synchro dead busbar side	<p>Normal/Inverse</p> <p>Related to the dead busbar mode, select NORMAL if Ekip Synchrocheck is on the dead busbar side</p>

Figure 31: electrical diagram of Ekip Synchrocheck



Annex B - Ekip Signalling

Ekip Signaling is a programmable contact module integrated in Emax 2 for Ekip Signalling 2k and Ekip Signalling 4k⁸, or available as an external Din-rail module called Ekip Signalling 10k.

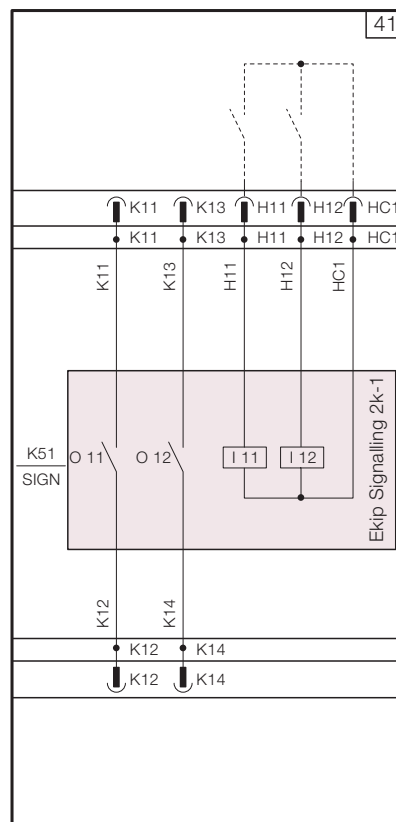
This last one is connected to Emax 2 thanks to local bus or Link bus (see Annex C).

For the Synchro Reclosing function, at least 5 outputs are required for the synchronization and the reclosing¹⁰ operations. Moreover, one input is needed to start the synchronization.

⁸ Ekip Signalling 4k is available for E2.2-E6-2 frames.

⁹ This Ekip Signaling contact maintains its position for at least 200ms. After this time has elapsed and if the paralleling circuit breaker is still open, the contact remains excited if the synchronism conditions are still verified. Otherwise, if one of the suitability condition for synchronism fails, the contact returns to the normally open position.

Figure 32: electrical diagram of Ekip Signalling 2k



Emax 2

Synchro Reclosing

Figure 33: electrical diagram of Ekip Signaling 4k

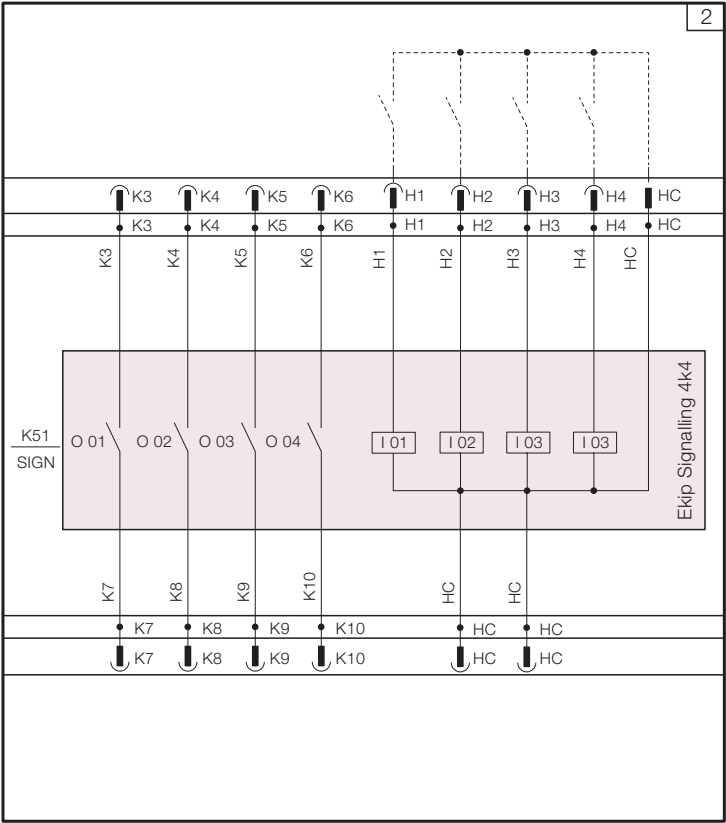
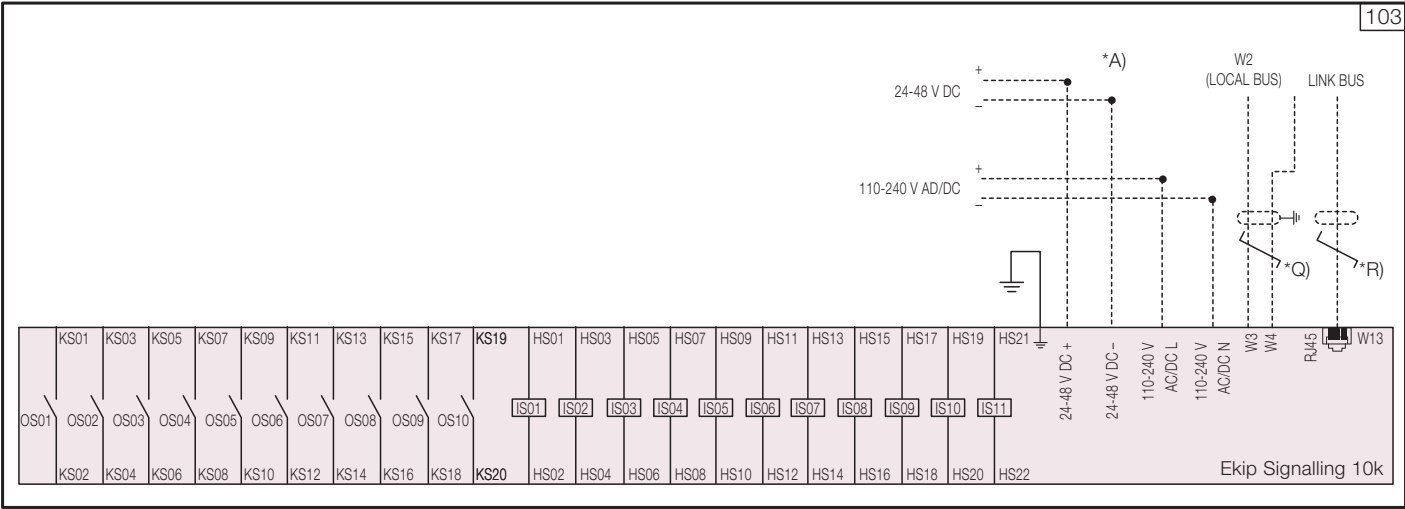


Figure 34: electrical diagram of Ekip Signalling 10k



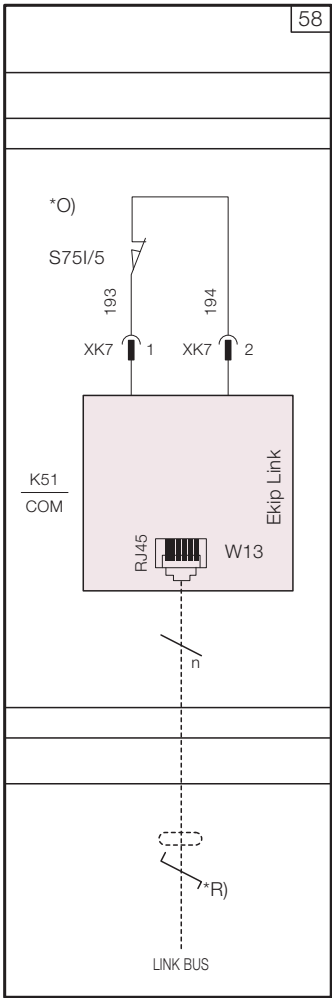
Annex C - Ekip Link

Ekip Link is the cartridge module that enables dedicated Ethernet network based on Link property standard. In the Synchro Reclosing function, it can be optionally adopted to connect Ekip Signalling 10k Din-rail module to Emax 2, in the cases where the controlled generator is physically distant from the main circuit breaker.

Figure 35: Ekip Link cartridge module



Figure 36: electrical diagram of Ekip Link



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