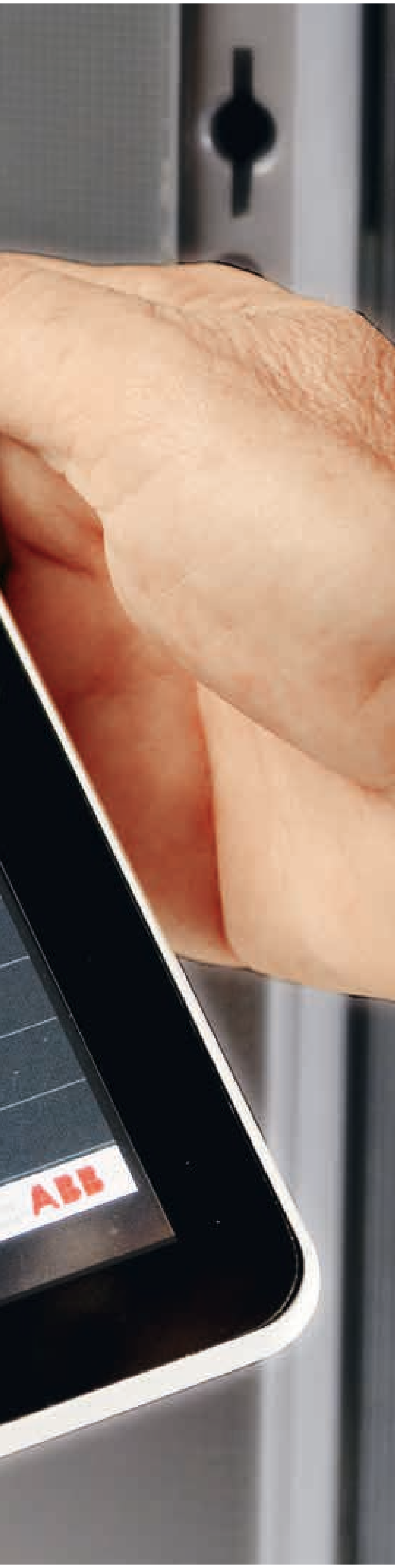

15:11
Ekip connect
Main Menu
Information
Status
Alarms
Trips
Measures
Statistics
Unit configuration
Protection parameters
Power controller
Modules
Programmable status
Measures History



Intelligent workload

A new circuit breaker that reduces breaks by optimizing loads

PIETRO ESPOSTO, PAOLO GRITTI, ENRICO RAGAINI – Humans may feel recharged after a power nap, but a break in electrical power does not provide the same feel-good factor. In an engineer's ideal world, all loads, supplies and environments would be created equal, predictable and reliable. But since the real world differs from the ideal, a new, intelligent automatic circuit breaker from ABB is stepping in to cope with what life throws at it. The first requirements of circuit breakers are about electrical performance (breaking capacity, voltage and current rating). Their use is widespread in electrical installations for protection and switching. In addition, they can now become an active part of the power management system.

Title picture
The Emax 2 circuit breaker also supports remote management via smart devices.

1 The reduction of cubile size possible with Emax 2.

Width of cubicle for breaker installation (mm)				
Circuit breaker	Current rating	Emax 2	Emax	reduction
E1.2	1600 A	350	490	29 %
E2.2	2500 A	490	630	22 %
E4.2	4000 A	600	880	32 %
E6.2	6300 A	1200	1260	5 %

Reduction of cubicle width achieved by installation of Emax 2 with respect to Emax. Cubicle depth also shrinks (eg, from 380 mm to 355 mm for current ratings of 2000 A and above).

All consumption demands are not created equal, and yet current supply systems frequently handle connected loads with total equality and no regard for criticality. ABB's Emax 2 is designed, engineered and produced to take all of these considerations onboard, optimizing the use of power, and taking these devices into the realms of intelligent breakers.

ABB is one of the technological and market leaders in low-voltage circuit breakers. A new step toward innovation in low voltage power systems is the new Emax 2 circuit breaker, released in March 2013. Emax 2 is an evolution of the well-established Emax air circuit breaker, which has been one of the top ABB products since 1995 with more than 1 million delivered. Emax 2 gives top performance a significant reduction in size compared to its predecessors → 1.

> The breaker can work as a sensor, an actuator and an active part of the distributed automation system.

High performance, small space, harsh environment

Circuit breakers often have to work in harsh environments: extremely low or high temperatures, humidity and vibrations. The electrical environment is equally harsh. Sometimes power quality will be extremely bad with high harmonic content and frequent interruptions. Extensive electromagnetic compatibility tests are performed to ensure that a breaker is insensitive to these influences.

Circuit breaker dimensions must be kept as small as possible due to the need for more compact switchboards. In some applications, space occupation is critical, for example in data centers and onboard ships, where each square meter occupied by switchgear is at the expense of payload.

In addition to reducing switchboard dimensions, such a compact design and reduction in size also means reduced use of copper, aluminum and steel, optimizing resources even further. The design, product engineering and production of Emax 2 considered the harsh physical and electrical environment in which the circuit breaker will have to operate. Engineering expertise, experience from past product series and new requirements from customers have been taken into account to deliver maximum performance and reliability.

Power systems become smart

Currently a wide-scale evolution is taking place in power systems: cities are evolving into smart cities, where power distribution grids will be intertwined with com-

2 Emax 2 circuit breaker family

Integrating automation into the breaker turns it into a real power management device.

munication networks. Digital "smart" devices will monitor the flow of power, to deliver energy where and when it is required and at maximum efficiency: This of course includes the circuit breaker.

Innovation in electronic technology allows more intelligence to be built into the digital protection unit. The breaker can work as a sensor, an actuator and an active part of the distributed automation system that manages the power distribution. The intelligent breaker is thus capable of processing information, storing information in memory, communicating data, and making decisions in an automated way. Integrating automation into the breaker is an especially significant technological improvement with respect to previous generations of products as it turns the breaker into a real power management device.

Because breakers are deep in the electrical installation, for protection of feeders and loads, making them smart means putting intelligence as close as possible to the loads. This is extremely effective as it allows maximum flexibility and fine granularity in the control of electrical power usage.

Embedding these new functions in the breaker provides additional advantages: Because the circuit breaker is normally installed in power systems for protection and switching, new functions can be added without the need for additional devices. The breaker has built-in current and voltage sensors, so new functions can build on what is already available: Current and voltage measurements data are already available for the purpose of protection, so the unit can use them also for power measurement, statistics, diagnostics, etc. Therefore, the need for compact switchboards can be fulfilled together with the new need for intelligence → 2.

Innovation in electronic technology allows more intelligence to be built into the digital protection unit.

The circuit breaker as a power manager

An electrical installation usually provides power to a large number of independent loads. Some of them absorb energy at a constant rate, but most vary their power consumption with time, for example lights in a building can be switched on or off randomly. HVAC systems turn on and off according to temperature, as do refrigerators.

Each electrical load contributes to the total energy consumption of an installation. However, there is, typically, no coordination among them: Each load switches its power consumption on and

3 Power Manager

1) Power Manager works by measuring the energy absorbed by the electrical installation since the start of the measurement slot (measurement window/ time frame). Total power is the rate of energy increase with time. Based on energy and power, an estimate of consumption at the end of the time frame is calculated.
2) When non controllable loads are turned on, power increases and Power manager estimates whether consumption at the end of the time frame will exceed the limit.
3) Power Manager switches off a controllable load (HVAC) for some minutes.
4) When total power decreases and the estimate is below the limit by some margin, Power Manager reconnects the controlled load.

4 Demand control application

1) Installation is powered by the grid and by local generation (Photovoltaic). Ekip Power controller measures net energy absorbed from the grid (difference between load consumption and local production).
2) If the power produced by PV decreases, Power Manager detects an increase in power flow from the grid. If an excess of energy consumption is estimated, one or more loads are disconnected.
3) Priority loads are kept connected all the time.
4) When PV generation resumes, Power Manager detects a decrease in net power flow from the grid, which eventually triggers a load reconnection.
5) Total load is therefore responsive to the availability of renewable power.

5 Ekip power controller

Ekip power controller controls the maximum power consumed by the installation, utilizing the same method as that used for fiscal metering, thereby achieving savings on the component connected to maximum power ($/kW) on electricity bills. The power consumed is calculated by the energy meter as an average value over pre-determined time periods such as, for example, 5 minutes, or even 2 hours.

Because power is measured as the average of a time slot, a larger consumption in part of a slot can be compensated by a lower consumption in another part, while keeping the total average power within the limits. For example small consumption in the first part of a period allows more tolerance toward larger consumption in the second half.

Ekip power controller uses this principle together with a predictive algorithm that estimates, moment by moment, power at the end of the period in order to decide whether to disconnect or connect loads and generators. This enables brief transient requests for high power to be tolerated, such as, for example, the starting up of motors, without causing the disconnection of loads as soon as the power exceeds the threshold set.

The operations of connection and disconnection therefore depend on the consumption from the beginning of the period up to the present moment. For example, if during the first few minutes of the period of reference consumption was very high, Ekip power controller will disconnect a greater number of loads in the minutes after; if, on the other hand, the initial consumption was low, it will leave a greater number of loads in operation.

Power controller is based on power measurement, which is integrated to obtain the total value of energy consumption. By its internal clock, time elapsed since the beginning of the time slot is known, so the average power can be calculated.

Based on these four quantities (actual instantaneous power, average power in current time slot, total energy and elapsed time), power controller uses a dedicated algorithm to estimate the total consumption at the end of the time slot. Based on such an estimate different actions are taken. If the estimated value is:

– Greater than the power set as a target, Ekip power controller makes the decision to disconnect one of the loads controlled from the power supply, or to connect a generator;
– Equal or slightly less than the average power set as a target, Ekip power controller makes the decision to leave the conditions of the controlled loads and generators unchanged;
– Significantly lower than the average power set as a target, Ekip power controller makes the decision to reconnect one of the loads controlled to the power supply, or switch off a generator if one or more of these have been switched on previously.

The predictive algorithm is run several times at different instants during the time slot, so that the prediction is updated and loads can be connected/disconnected accordingly. The goal is to track actual power consumption and prevent it from exceeding the limit. Meanwhile, whenever power consumption decreases, previously disconnected loads can be reconnected, thus preventing unnecessary off-time.

This operation is carried out cyclically each time by calculating a new estimate: therefore, if the estimate of power consumed continues to be too high despite the fact that a load has been disconnected, Ekip power controller will proceed to disconnect another load and so on, until the power limit is respected. In this way, the number of connected or disconnected loads varies dynamically, and always with the guarantee that only the minimum number needed to respect the power limit are disconnected.

off in an independent way. If several loads are switched on at the same time, sharp peaks can appear. These peaks have several undesirable effects:

– They increase the maximum active power demand and based on the type of contract with the electric utility, additional fees might be applied.
– They might cause overload alarms and even protection trips. In order to avoid this, designers of the installation may consider oversizing, which means more using expensive components.
– On a larger scale, the electrical system will need reserve generating capacity to deal with them.

Power peaks are the result of a lack of coordination between different loads. The presence of a power manager, which prevents too many loads from consuming too much at the same time, can be very effective in limiting, or "shaving", power peaks. Emax 2 is such a power manager. Its principle is very simple: When power consumption becomes too high, operation of some low-priority loads is delayed by some seconds or minutes, up to a moment when conditions allow them to be reconnected.

In many low-voltage systems, there are often several loads that do not require a continuous power supply and that can be delayed in their operation for a short time without the user even noticing. For example, if an air conditioner is switched off for a minute, the overall effect on the temperature is practically unnoticeable. This delay can however, allow other time critical loads to start and run at peak power for a short time without the total power exceeding the set limit.

Emax 2 Power Manager's advanced real time control system uses this logic to limit the power absorbed by an electrical installation. It works by disconnecting some "controllable loads" or "delayable loads", which are then reconnected when it becomes possible without ex-

6 Generator-powered marine installation

1) Several generators are connected in parellel. Installation is operated as a closed loop (all the circuit breakers are closed), for maximum availability. Typical voltage is 690V.
2) When one generator is started, the synchro check embedded in the circuit breaker prevents connection unless its frequency and phase are aligned to the test of the installation. The breaker will signal automatically when conditions are met.
3) In case of a fault, directional protection and digital interlock make each of the breakers in the loop aware of the fault location. Breakers operate as an integrated system, and only those facing the faulty section of the installation trip.
4) Only the section of the plant where the fault is located is put out of service. Power flow to the rest of the plant is maintained throughout the fault.

7 User friendly graphic menus

ceeding the power limit. The power controller constantly optimizes the number of disconnected loads, while continuously trying to supply the largest possible load to the plant. Controllable loads are connected and disconnected by slave breakers, either of Emax 2 or legacy type, which are opened and closed on command. Instead of disconnecting loads, the Emax 2 Power Manager can connect auxiliary generators when load demand requires it. Signaling the connection and disconnection of generators is also managed automatically, as part of the same strategy for dealing with loads. The connection and disconnection of loads is coordinated so that the total power is kept as much as possible below a set limit → 3. This limit is, typically, related to the maximum power demand agreed with the utility.

> In many low-voltage systems there are often several loads that can be delayed in their operation for a short time without the user even noticing.

Another possible application is to make power demands responsive to the availability of renewable power generation → 4. If two power sources are available, perhaps grid and photovoltaic (PV), total power absorbed by the grid will be the load consumption minus the local generation. If PV is not available, the Emax Power Manager will measure an increase of absorbed power and disconnect one or more loads. When PV power becomes available again, a decrease of net power flow will be measured, so the Emax Power Manager will reconnect loads. This kind of demand response application works in real time, based on local power management, and it can be used in stand-alone configurations.

The Emax 2 circuit breaker has an integrated electronic unit, that implements all of the protection, measurement , control and communication functions. It is sometimes called the protection unit, or trip unit, or release. The product name for the electronic unit within the Emax 2 is Ekip. The power controller is one of the functions implemented by Ekip, in addition to its other tasks, such as protection. In future applications, the Emax 2 power controller will be used to make power demand responsive to day/night conditions, or energy market price → 5.

When power consumption is high, the storage can be connected in “discharge” mode. When power consumption is low, the available margin can be used to charge the storage system.

8 Touch-screen interface

Finally, it is possible to use the Emax 2 power controller to trigger charge/discharge operations in a storage system. When power consumption is very high, the storage can be connected in – “discharge” – mode to help feed the load. Then, when power consumption is low, the available power margin can be used to charge the storage system.

Applications are packaged as plug and play modules, which makes them extremely easy to put into service.

Protecting local generators

It is becoming increasingly common to see more and more local generators connected to low-voltage distribution grids. The diffusion of PV and small combined heat and power (CHP) generators is apparent and industrial and marine systems already use local generators to a great extent. Protecting local generators from faults is sometimes a technological challenge. Two issues are especially critical:

- When a generator is used to power a microgrid in islanded mode, ie, disconnected from the main grid, frequency variations should be closely monitored. The rate of change of frequency should be used as a fault indicator, so specific protection is required.
- If power is provided by a solid-state generator (eg, the inverter of a PV plant), short circuit currents are typically low. This makes it difficult to detect short circuits for the traditional overcurrent protection. A more sophisticated strategy is to detect current increases associated with a significant drop in voltage, which is typical of short circuit conditions.

Both the above aspects are addressed by Emax 2, which includes specific protection like rate of change of frequency (ROCOF) and 51 V, ie, overcurrent protection controlled by voltage value. Both are implemented here for the first time inside a low-voltage circuit breaker.

Additional Emax 2 features address installations where multiple power sources are present:

- Synchro-check prevents connection of a generator when its voltage is not in phase with that of the system. This function is normally implemented by a separate device, now it is integrated into the breaker.
- Directional protection with logic interlocking (also an exclusive ABB

9 Emax 2’s plug and play modules

A large number of terminals and accessories accommodates the maximum variability of connections.

feature for low-voltage breakers) allows maximum availability in multiple power source systems, by automatically detecting the location of a fault and minimizing outages.

An example for a marine power system is shown in ➔ 6.

Easy to use, easy to engineer

As power systems become more and more complex, applications such as those described need quite complex algorithms. In spite of this, Emax 2 remains extremely simple to configure and use. Only the basic parameters have to be set by the user and all tuning is via a specific software that performs all the calculations, meaning the user does not have to be distracted by the complexity. The trip units use graphic menus, either with front panel keypad or touch-screen, which makes it extremely intuitive and user-friendly to use the applications ➔ 7–8.

Most applications are packaged as plug and play modules, which makes them extremely easy to put into service ➔ 9. It is even possible to install such modules in the field. When new functions are added to an existing plant, for example, when a generator is connected to a busbar, the generator protection can be added to the breaker that protects the busbar.

From the engineering point of view, designing the mechanical structure of a switchboard for installation of a breaker is sometimes challenging and Emax 2 includes a large number of terminals and accessories, to accommodate the maximum variability of connections (cables, copper or aluminum busbars, etc.).

In order to save engineering time and effort the product documentation is also innovative. Video manuals and 2-D and 3-D drawings are provided in electronic format. For installation designers, white papers and technical application papers describe the new products and how to correctly select and apply the new Emax 2 breaker.

Pietro Esposto
Paolo Gritti
Enrico Ragaini
ABB Low Voltage Products
Bergamo, Italy
pietro.esposto@it.abb.com
paolo.gritti@it.abb.com
enrico.ragaini@it.abb.com