Simply XTraordinary

Introducing ABB's new Tmax XT family of highly advanced molded case circuit breakers

LARA CORTINOVIS, LUCIO AZZOLA – A circuit breaker is one of the most important and essential safety mechanisms in modern electrical systems. Many different classifications of breakers can be made, based on voltage class, construction and interrupting type, and structural features. However, current market trends indicate that customers are looking for more modular, flexible and integrated circuit breakers and ABB has responded with its new family of high-performing molded case circuit breakers. This family, known as Tmax XT, contains four devices that can be used for distribution, motor and generator protection, oversized neutral and as switch-disconnectors. They are available as three or four-pole versions that can be fixed, plugged in or easily withdrawable, and are fitted with the very latest generation of interchangeable, precise and reliable thermomagnetic and electronic trip units. And uniquely, a new and large number of dedicated accessories are available to meet the most stringent of applications.

ABB's new generation of Tmax circuit breakers are standard-compliant, modular and intelligent devices that can be easily integrated or interfaced with other components or systems.

ABB has been designing and producing low-voltage molded case circuit breakers (MCCBs) and air circuit breakers (ACBs) since 1934. The first family in the MCCB series, known as "Isol," featured a thermomagnetic trip unit (TU) and was characterized by a maximum breaking capacity of up to 25 kA (at 415 V AC). Each decade following the launch of the Isol family saw the emergence of new generations of MCCBs, including the Fusol, Modul, Limitor and Isomax families. The well-known Tmax T family of circuit breakers was launched in 2001.

The last ten years or so have seen some dramatic changes in customer and market demands that have in turn affected suppliers. For example, new and improved applications necessitate greater speed and reliability in a protection system to maintain safety, stability and continuous service. For suppliers – many of which have emerged in the last decade – this means the development of standard-compliant modular, smaller and intelligent devices that can be easily integrated or interfaced with other components or systems.

ABB's new generation of Tmax circuit breakers, the Tmax XT, are examples of such devices (*see title picture*). Characterized by high performance in a small device with the most modern electronic TUs, this family of circuit breakers combines over 60 years of experience and know-how in breaker design with modern technological developments.

The Tmax XT family album

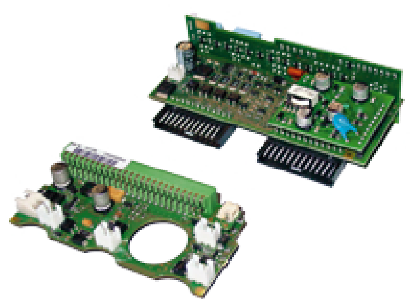
The Tmax XT family is composed of four frames (XT1, XT2, XT3 and XT4) with a rated current that extends up to 250 A and a rated ultimate short-circuit breaking capacity, Icu, that goes up to 150 kA (at 415 V) and 90 kA (at 690 V):

- XT1 (160 A) with an Icu up to 70 kA (at 415 V)
- XT2 (160 A) with an Icu up to 150 kA (at 415 V)
- XT3 (250 A) with an Icu up to 50 kA (at 415 V)
- XT4 (160 – 250 A) with an Icu up to 150 kA (at 415 V)

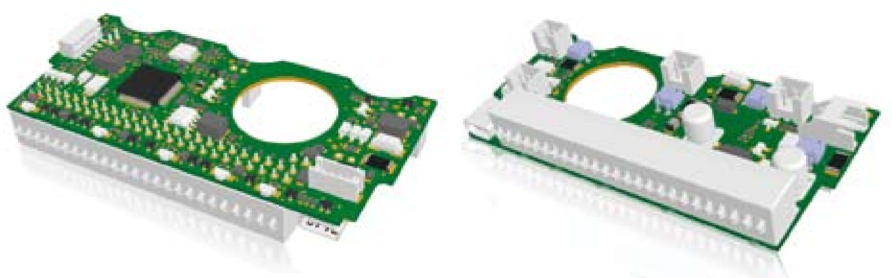
The XT1 and XT3 frames can be used in large scale distribution installations, hospitals and generally in all service-sector applications that require high reliability, while XT2 and XT4, with the highest breaking capacities on the market, are more suited to heavy industries, metallurgy and marine (cruises, oil rigs, container ships), where extremely high performance is required. Unique to the market, these two frames can be equipped with the latest generation electronic TU, allowing interchangeability and integrated communication from rated currents of 10 A.

XT1 and XT3 are both available in the three and four-pole fixed and plug-in versions. With a depth of 70 mm and a compartment door cut-out of 45 mm, they can easily be installed, side by side, on a DIN rail or on a back plate without using spacers.

1 Old Tmax trip unit (TU) size versus the new TU size



2 3D views of the new TU printed circuit board (PCB)



Innovation in research and development

In order to reduce the development and validation time needed for the breakers and to increase project quality, ABB engineers developed advanced design tools that could be used during the initial design phase:

- A common design platform to develop, select, integrate and interface the individual components of the Tmax XT breaker family
- Multi-physics simulation to design and calibrate the full range of Tmax XT over-current relays
- An Arc Imaging System (AIS) that allows the optical diagnostics of low-voltage arcs
- The highly accelerated life test (HALT), which exposes failure modes, allowing corrective action to be taken in the design or production process

A common design platform

One of the requirements for the new "Ekip" electronic TU (used in the XT2 and XT4 frames) was enhanced performance in a smaller device. While greater performance generally means increased complexity, calculation power and functionality, all this is now possible in a unit that is 50 percent smaller than its predecessor → 1 and → 2. To achieve this, the designers first looked at the core of the unit and selected a very powerful 32-bit ARM [1] microcontroller, which is characterized by its high energy efficiency and high performance using a single processor architecture in a small footprint. It provides a high level of connectivity, allowing the integrated development of different communication buses.

Then it was necessary to develop, select, integrate and interface the individual components of the complete mechatronic assembly, ie, the plastic box, current sensors and terminals, electronic TU, trip coil and interconnections → 4, at the same time. This included ensuring the correct components were chosen, their most optimal position on the printed circuit board (PCB) and observing how they integrated with other mechatronic assembly components. These steps were possible using a common design platform long before the physical construction of the assembly began.

Thanks to its scalability and wide availability, this platform can be reused as a basis for future developments that feature a high level of software code portability (ie, the same hardware and software platform). This guarantees a reduction of time to market and increased reliability. The firmware has been developed according to international software quality standards, such as the UL489 supplement SE [2], and the latest software engineering guidelines.

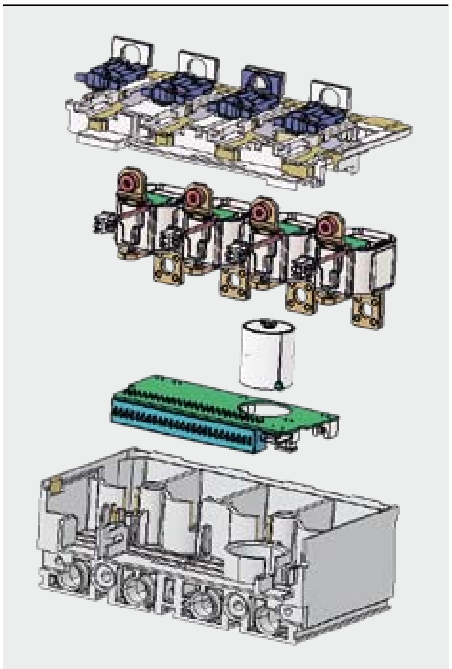
The Ekip TU is a complete series that provides protection for plants at 400 Hz (eg, airports, ships). To ensure this, an extensive frequency analysis is needed, which requires the right current sensor (CS) frequency response, an adequate analog channel bandwidth for the measurement of harmonic components and correct digital filter design for accurate signal reconstruction → 4. These requirements are executed using Simulink and Matlab simulation tools.

Footnotes

1 ARM, headquartered in Cambridge in the United Kingdom, is the industry's leading provider of 32-bit embedded microprocessors.

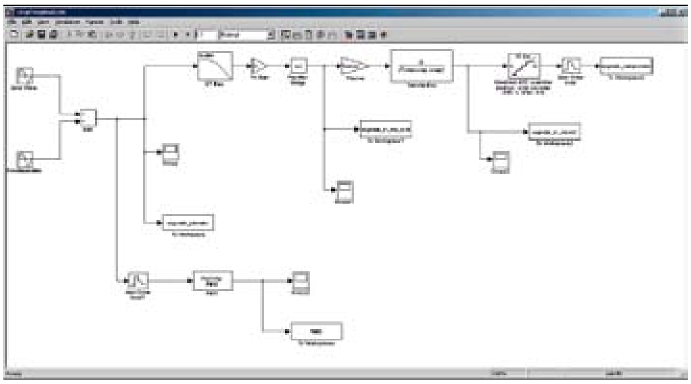
2 The UL489 supplement SE standard outlines the requirements for molded-case circuit breakers and molded-case switches with software in programmable components.

3 Breaker mechatronic assembly view



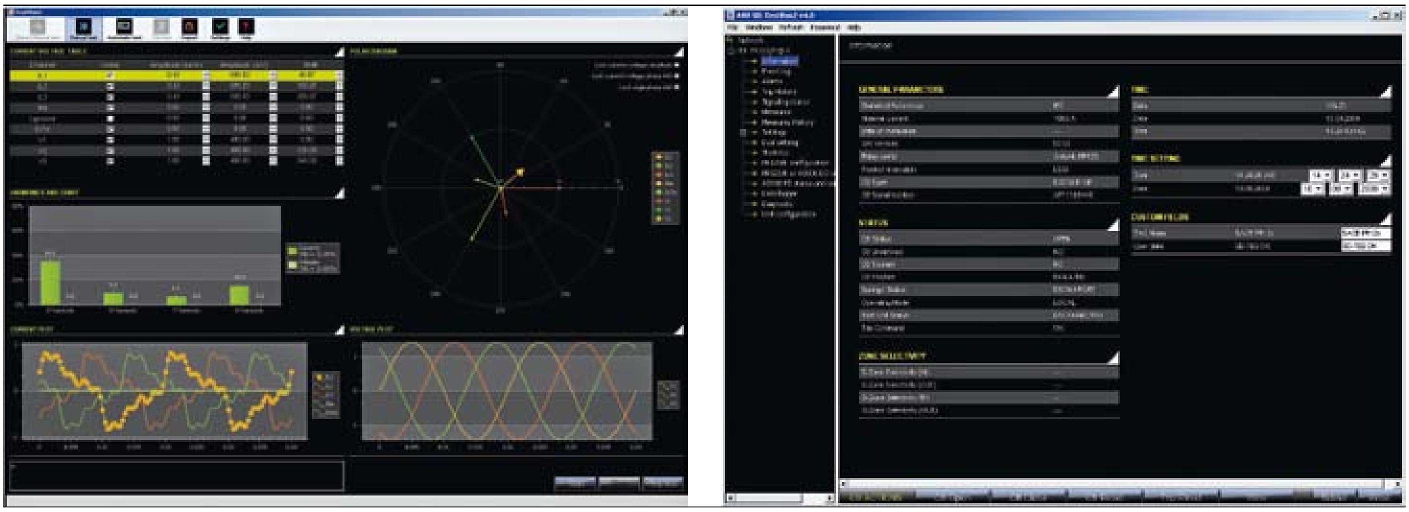
The Tmax XT family of breakers contains four devices that can be used for distribution, motor and generator protection, oversized neutral and as switch-disconnectors.

4 An example of a hardware and software simulation model for frequency analysis



5 Tmax XT Ekip display

6 Tmax XT Ekip Connect screenshot



The functionality of the Ekip TU can be extended by means of plug and play accessories, such as an LCD graphic display with backlight (Ekip display), an LED meter, a local communication interface (Ekip T&P and Connect), a system communication interface (Ekip COM), and a device for trip test and last trip detection. The Ekip display, an innovative device for ABB MCCBs, is a graphical HMI that allows the local configuration of enhanced TU functions that were previously only available via a communication bus or handheld device → 5. The display is powered directly by the TU and it is a plug and play device that can be easily moved from one TU to another. The Ekip T&P enables the TU to directly interface with the USB port of a PC and it works together with Ekip Connect, a software tool for supervising, setting and testing → 6. The Ekip COM is a module that can be embedded into the circuit breaker and provides an interface between the TU local bus communication and the system bus. Moreover, it is possible to remotely control the TU and the circuit breaker with motor operating equipment.

Multi-physics simulation

A bi-metallic strip is a mechanical device that transforms a change in temperature into a change of shape, and because of its simplicity, reliability and the low cost of production, it is considered the most common solution for MCCB over-current protection. Even though the working principle of bimetals is well documented and known for many years, designing and calibrating the full range of Tmax XT over-current relays has been quite a challenge because of the technical specifications that have to be met, including:

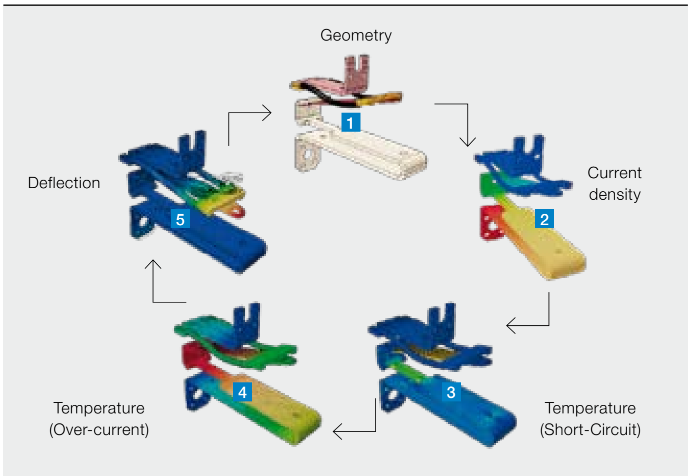
- A low regime over-temperature with rated current In
- Low sensitivity to environmental temperature
- A non-tripping current of 1.05 × In
- A tripping speed with 1.3 × In of less than 10 minutes
- A tripping speed with 2.0 × In of less than 3 minutes
- A tripping speed with 6.0 × In of less than 20 seconds
- Reduced temperature rise during a short circuit (Icu, Ics).

In order to meet these conditions, which involve different branches of physics, an iterative multidisciplinary procedure has been implemented → 7. Starting from an approximate geometrical configuration (material properties included), a sequence of electrical simulations at imposed current rates provide the relevant heat sources for the subsequent thermal computations. Once the satisfactory temperature distributions are obtained, all mechanical unknowns (deflection, speed and the force of the bi-metal) become available. The initial geometry is therefore revised until all of the aforementioned conditions are fully met.

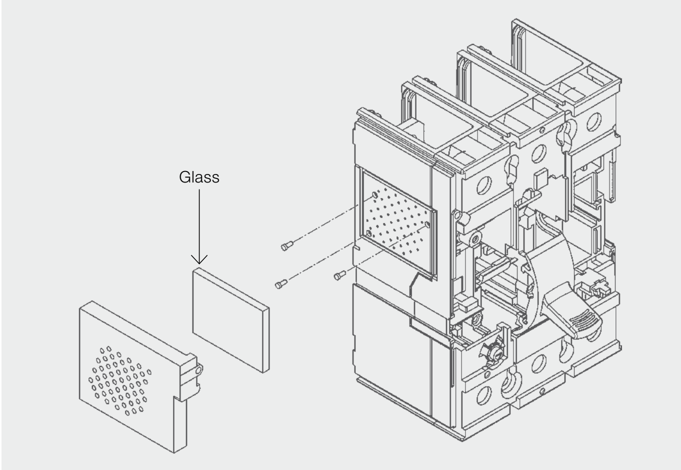
Compared to the classical analytical approach, this procedure revealed two advantages:

- It has a wide range of applicability (from the higher to the lower currents)
- It is geometrically independent (every solution can be analyzed).

7 Multidisciplinary procedure



8 To monitor arc movement optical fibers are placed on one side of the breaker with a protection glass interposed.



9 Overview of the Arc Imaging System (AIS)

The highly accelerated life test (HALT), is based on the accelerated tests principle and is performed directly on complete breakers, accessories and single components in the design phase.

Optical diagnostics of low-voltage arcs

The study of short-circuit interruption is challenging for designers. For example, during an interruption the arc plasma can reach temperatures of up to 20,000 K and needs to be extinguished very quickly. An enhanced technique, the Arc Imaging System (AIS), has been developed to observe arc movement during a short circuit. It consists of an array of optical fibers, mounted on one side of the breaker, which read the light intensity inside the arc chambers ➔ 8. The acquisition system, developed together with the University of Southampton, is a self-contained mobile system supplied with a range of optical-fiber lengths ➔ 9. It comprises a purpose built PC, and an integrated computer screen and keyboard. The system hosts a total of six cards, each capable of accommodating 16 channels for data acquisition (giving 96 channels in total). The hardware is assembled on vibration proof mountings and can be sealed for transportation.

An automatic post-processing routine has been developed which produces a movie of the arc evolution: stills of one example are shown in ➔ 10. In other words, for any sampled time instant, the light intensity value from each fiber is mapped onto a suitable color scale and superimposed to a picture of the circuit breaker arc chamber in the correct location.

AIS has proved to be an amazing tool in that it correctly interprets the outcome of a test and, analyzed together with test lab oscillograms, has contributed enormously in clarifying many aspects of current interruption.

The highly accelerated life test (HALT)

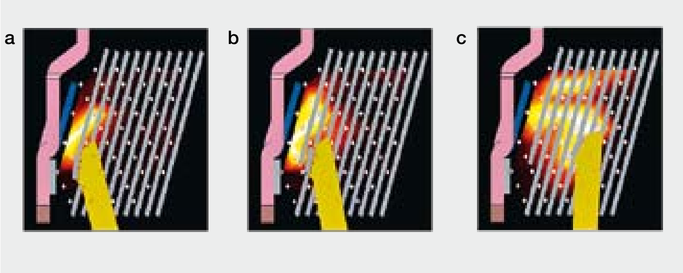
Tmax XT breakers have been developed using modern techniques, which have led to increased reliability and robustness. They have also been designed and tested in accordance with the requirements of all the relevant international standards as well as the Naval Register requirements. One of the approaches implemented, the highly accelerated life test (HALT), is based on the accelerated tests principle and is performed directly on complete breakers, accessories and single components in the design phase.

The goal of HALT is to quickly break the product and learn from the failure modes the product exposes. The key value of the test lies in the failure modes that are uncovered and the speed at which this happens. Under real conditions, it could be years before these failure modes actually appear. HALT is considered a success when failures are induced, the failure modes are understood and corrective action is taken in the design or production process ➔ 11.

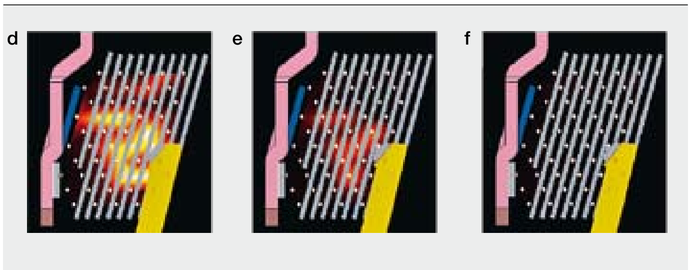
According to the HALT procedure, the product is stressed far beyond its specifications and typical environmental conditions. The actual functional and destruct limits of the product are found and extended as far as possible (for example, vibration up to 40 g, temperature from –80°C to 180°C and thermal shock with a ramp rate of 15°C/min) ➔ 12.

Every step of HALT foresees:
– Test design, using the design of experiment (DOE) technique, to define the appropriate number of samples and variables

10 A successful interruption captured using the Arc Imaging System (AIS)

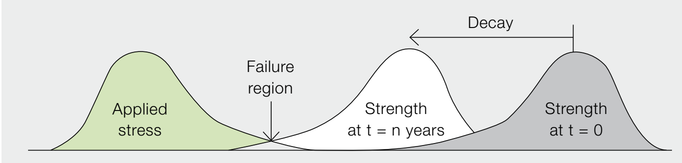


a Contact repulsion and arc ignition (1 ms)
b Arc movement from the contact to the arc runner (2 ms)
c Arc expansion in the arc chamber (3 ms)

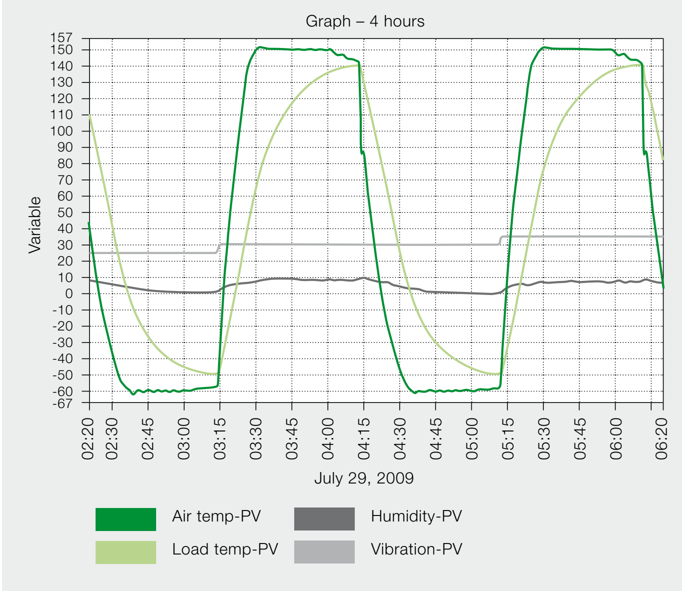


d Arc cooling (4ms)
e Electrical rigidity almost restored (5 ms)
f End of the phenomenon: successful current interruption – (6 ms)

11 Stress-strength in the HALT sequences



12 A HALT testing cycle



– The execution of the tests with the HALT procedure at defined stress levels and step durations
– The result analysis, which is performed by fitting a failure with statistical models, such as Arrhenius' law for thermally driven failures; Eyring's theory for temperature and humidity; the inverse power law (IPL) for pressure, mechanical stress; voltage supply and thermal non-thermal (T-NT) (eg, temperature and vibration)

Tmax XT circuit breakers are developed and produced in accordance with the RoHS Directive, and the LCA approach was used to assess and minimize products' environmental impact.

Overall, this approach improved the XT developing process, gave the designers a greater insight into the expected behavior during the product life and reduced time to market.

A lifetime of experience

ABB's new Tmax XT circuit breakers have been made to respond successfully to all plant engineering requirements, from the most standard ones to the technologically advanced ones. They feature a new range of both thermomagnetic and electronic protection plug and play trip units, which are interchangeable right from the smallest frame and which guarantee absolute tripping reliability and precision.

In addition, the circuit breakers are designed with the environment in mind, ie, they are developed and produced in accordance with the Restriction of Hazardous Substances (RoHS) Directive and other environmental regulations concerned with such substances. In addition the life cycle assessment (LCA) approach was used to assess and minimize products' environmental impact in terms of emissions, resource depletion and waste throughout the whole life-cycle, from manufacturing to disposal.

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