The Intelligent AX1 Switchgear for Medium Voltage

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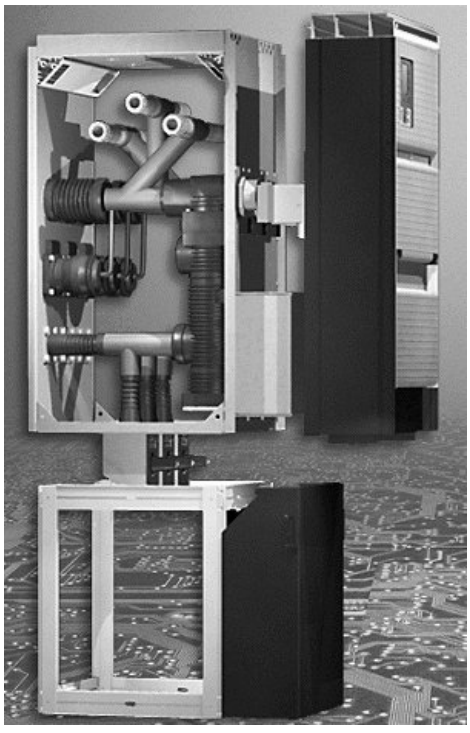
Abstract
The newly launched medium voltage switchgear AX1 represents a new and functional approach to the switchgear architecture, consistently utilising new technology without the limitations given by the old type components. Besides the incorporation of software intelligence, it also results in many general advantages, such as compactness, easy installation and high personnel safety and service reliability. AX1 may even house a trolley with the battery system for the auxiliary supply. The protection relays and operating push-buttons are replaced by bay computers handling all protection, operation and the interlocking between the apparatus in the switchgear. The modern control system needs less wiring.
The basic philosophy for the switchgear architecture is to keep all high voltage parts in one separate compartment, and all mechanical and auxiliary parts fully accessible outside the high voltage compartment. Parts needing access, like auxiliaries and circuit breaker actuators are in this concept fully and safely accessible, also when the high voltage parts are alive and the circuit breaker is closed.
The switchgear is supplied with a specially developed and extremely fast "Arc Eliminator".
The concept is designed for fast and simple installation on site. The cubicles have sliding doors, safely keeping the operating area free for the operating personnel, and limiting the needed space.

1. A new switchgear architecture for modern technology

1.1 Philosophy

The standard IEC 60298 for AC metal-enclosed switchgear and controlgear , 1 – 52 kV, defines three different types of architectures: Metal-clad, compartmented and cubicle switchgear and controlgear. With the new switchgear AX1 a completely new architecture is introduced, not defined by the standard.

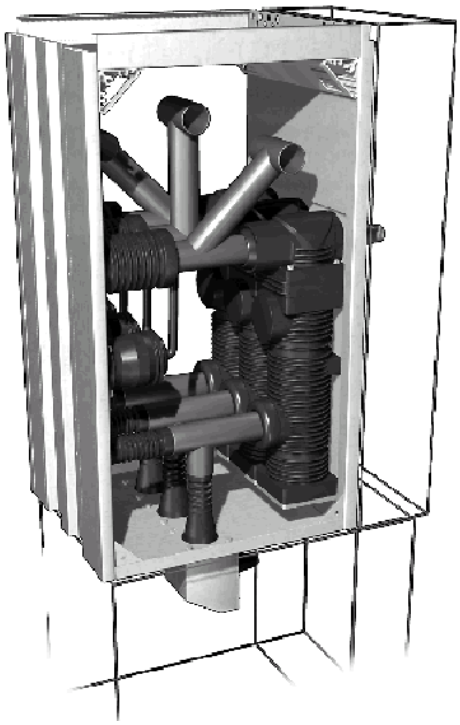


The definitions of metal clad and compartmented switchgear – switchgear with different compartments for at least the circuit breaker, the bus-bar and the cable connection – is based on the old technology with old type of high voltage components, needing regular access for maintenance. The basic function of the separate compartments is to protect personnel from accidental access to live parts when doing different maintenance work on other parts of the main circuit. A second function, not foreseen by the IEC standard but often supposed to be fulfilled, is the limitation of the failure and the damage in case of a severe failure under conditions of arcing due to an internal fault. The verification of this limitation is in fact not defined by the test according to the standard. Both those functions are however solved in a completely different way by the AX1 switchgear.

1.2 Secluded high voltage compartment for the main circuit

The basic idea with the new switchgear architecture is to install all parts of the main circuit in a separate compartment with limited access to personnel. Modern high voltage components normally need no maintenance and no easy access, except possibly for the actuators. The main circuit compartment of AX1 actually forms a strong encapsulation of its own. Access to this encapsulation is only possible through a bolted wall, being a part of the circuit breaker frame. The advantage of no regular door of the high voltage compartment is an extremely safe protection to personnel in front of the switchgear. This means protection both against accidental access to the high voltage parts and against the result of an internal arc. The test to prove the safety in the case of an internal arc is not valid for the case of an open door.

The *main circuit compartment* is common for all cubicles in the section of the switchgear. This layout has several advantages: Simple installation, improved cooling, a better dielectric and more compact solution. It also means a lower internal pressure in case of an internal arc. Any damage by an arc is effectively avoided by the Arc Eliminator, see below.



Actuator for disconnector/earthing switch

1.3 Actuator compartment makes the breakers accessible

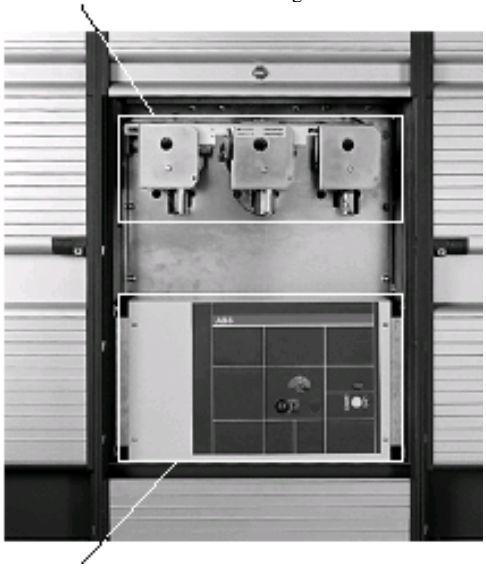
Experience from both SF6 and vacuum circuit breakers shows, that the only part of the breaker that might need access for maintenance is the mechanical actuator. All actuators are easily accessible inside the separate actuator compartments of AX1.

In a metal-clad switchgear access to any part of the circuit breaker is impossible without withdrawal of the whole circuit-breaker from the circuit breaker compartment. This means that the circuit has to be opened, as well as the enclosure for the high voltage part of the switchgear.

The separate actuator compartment makes it possible to maintain and even replace the whole actuator without opening the circuit breaker, which is safely locked in its position during this operation. All auxiliaries for the breakers and disconnectors are completely outside the main circuit compartment.

SF6 circuit breaker poles are also accessible from the actuator compartment for refilling of gas, even with the circuit breaker in service. With modern equipment this is normally not needed, but the possibility is favourable in the few cases.

A suitable name for this circuit breaker arrangement is *Accessible Circuit Breaker*, since the whole breaker is always accessible for the most relevant cases of maintenance. The poles inside the main circuit compartment are connected with plug-in contacts to the bus-bars and are possible to exchange after de-energising of the bus-bars. This is however a very rare case of maintenance.



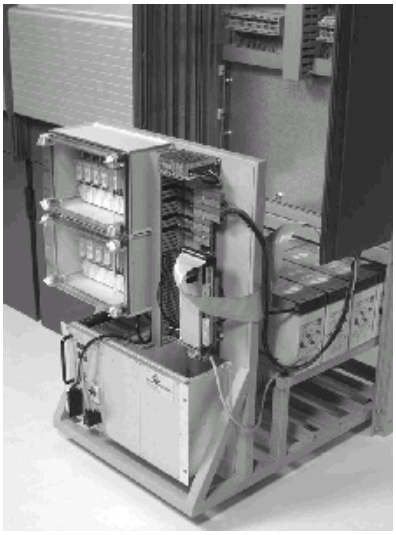
Actuator for circuit-breaker

1.4 Standardised control compartments

The control compartment is located on the top of the actuator compartment. AX1 is controlled and operated through a bay-computer with different sets of software. The modern technology with the functions defined in software, makes it possible to standardise the wiring and make the whole customisation in the software. All the wiring is prefabricated before the assembly in the factory. This improves the final quality and simplifies future maintenance. The total wiring is also heavily reduced compared with conventional technology.

1.5 Support cubicle as outside interface with integrated auxiliary voltage supply

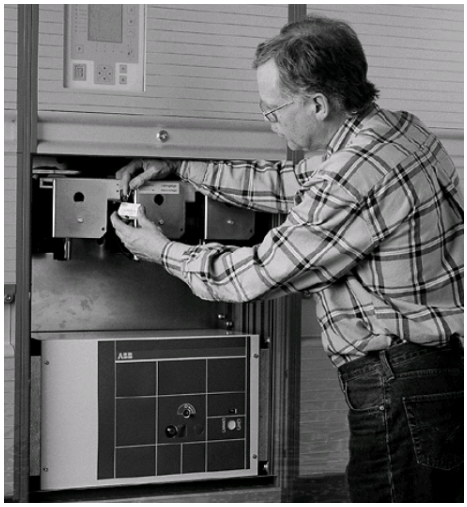
All outer connections for control are collected in one separate cubicle, sometimes equipped for special function, like revenue metering. This cubicle may also be equipped with a trolley housing batteries for the auxiliary supply. The battery loading and monitoring unit is integrated in the trolley. This offers a very compact solution for many cases, when a special place for this equipment is not necessary.



The battery system is mounted on a withdrawable truck in the support panel.

2. High service reliability and maximum safety for the personnel

Service reliability and safety for the operating personnel are in many ways two sides of the same coin – Occurring problems of one of the sorts often implicates the other. Some features of the AX1 concept are specially contributing to high reliability and safety.



2.1 Electrical operation and interlocking with integrated monitoring

The safest possible operation is the remote electrical operation, which is a standard feature for both circuit-breakers and disconnectors. Operations may also be made locally, but always electrical. This means that also the interlocking between different apparatus are electrical, as a part of the software for operation and control.

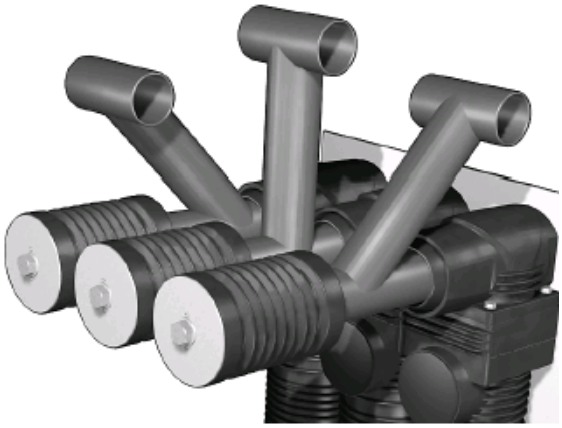
The disconnector replaces the racking mechanism for withdrawal of the whole breaker, compared with the metal-clad switchgear. A disconnector is generally a more reliable component than the more complicated racking mechanism.

The disconnector and the circuit breaker co-operates in the cable-earthing operation. The disconnector first disconnects the circuit breaker from the bus-bar and connect it to the earthing bar of the switchgear. This is of course made with the circuit breaker in open position. After that the circuit breaker is closed and connects thus the cable to the earthing bar. The circuit breaker is a very reliable earthing switch, capable of a big number of closing operations with full short circuit current. The whole operation sequency is made automatically at one command. Earthing of the bus-bar is a very rare case for this switchgear, since all important parts for maintenance are accessible from outside.

All electrical functions have a high degree of built-in monitoring.

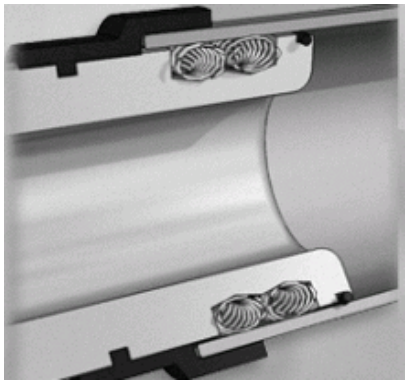
2.2 Bus-bar technology for high service reliability and compact dimensions

AX1 is an air-insulated switchgear for maximum 24 kV of about the same size as a gas-insulated switchgear for the same rating. The total dimensions have been minimised by the optimisation of the design from dielectric point of view. The bus-bar system is made of copper tubes, having the ideal geometrical design for an even dielectric field and for the best conductivity per area. The connections are either welded or of a special plug-in design with a helicon spring with a very low total resistance. This way the dependency of the mounting and ageing of a bolt connection is avoided.



Uniformed electromagnetic fields make a compact design with small phase-to-phase clearances.

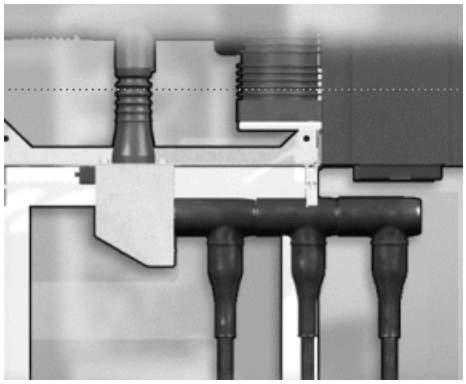
The bus-bars are built from round tubes, having the ideal electrical field and the most efficient current carrying capability. The connetions between the tubes are either welded or made by special flexible spring-contacts. Both those contact types are more reliable than the conventional bolted contact, which is dependant from the assemble quality and affected by temperature cycling and material saturation.
The spring contacts are formed as a helix with many turns, resulting in a high conductivity and flexibility. The contacts are silver plated, greased and covered with a rubber protection gasket to increase the resistance to aggressive environments.
Even though the bus-bar concept is relatively new, the type of spring contact has been used for many years in high voltage circuit breakers with a very good experience.



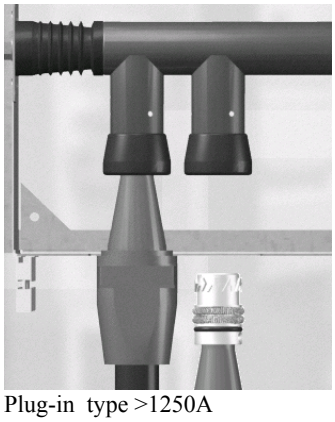
The O-ring and sealing gland protect the coil springcontacts as per degree of protection IP6X.

2.3 Pre-fabricated touchable cable connections

The old type of on-site fabricated cable connections has caused many flash-overs, when not properly made. They may also be destroyed by mice, if they can enter the switchgear.
AX1 is designed only for pre-fabricated cable connections. For ratings up to and including 1250 A regular outer-cone connections are used. For higher currents a new type of plug-in connections has been developed. The connections to the switchgear are single-phase and covered by metal, in principle touchable. This simplifies the design of the cable compartment, since open arcs cannot occur in this compartment.



Outer cone cable termination for max 1250A



Plug-in type >1250A

2.4 Internal arcs immediately eliminated

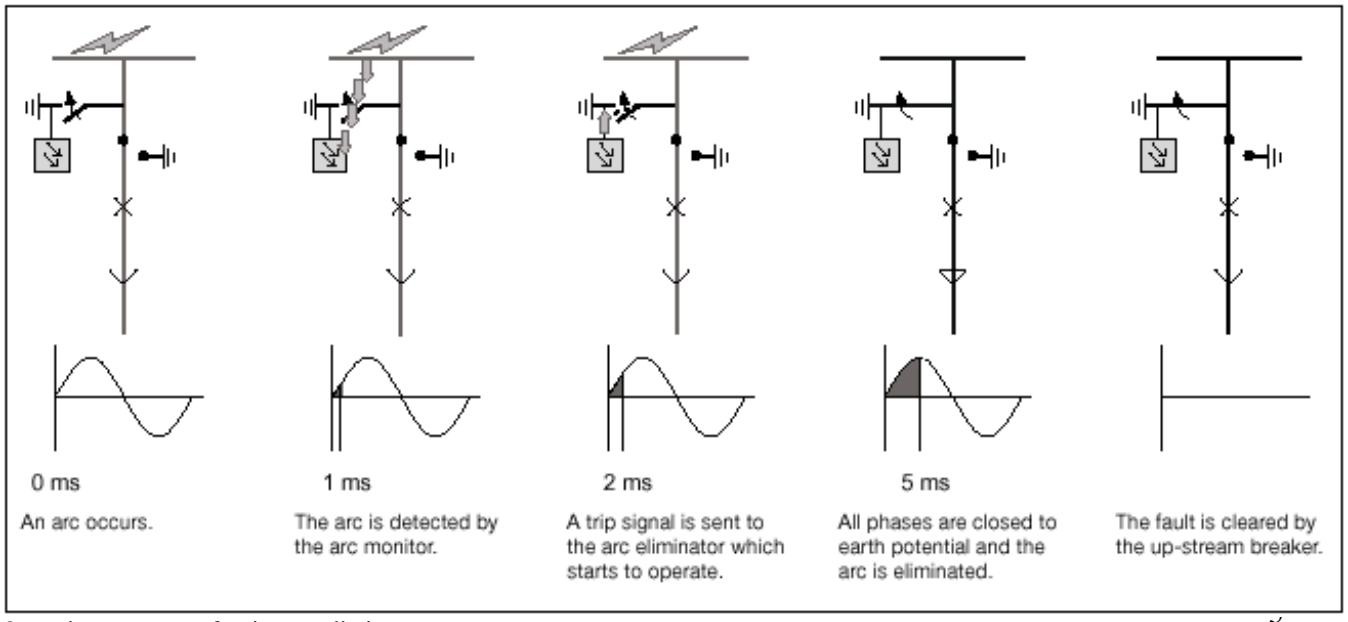
An open arc due to a severe fault in a switchgear is basicly prevented by a good design of the switchgear and its components, including the prevention of animals to enter the high voltage enclosure. The hazard to personnel in front of the switchgear in case of an internal arc is evaluated by the special type test according to IEC 60298. This is not a mandatory test, but more and more demanded by the switchgear users. It proves the resistance of the encapsulation to the high temperature and the following high pressure caused by open arcs inside the encapsulation. It does not deal with the poisonous gases created by the arc burning in air on copper bars. If those gases (nitrous and others) are let out in the switchgear room, this will become a very dangerous place for the personnel.

Both the hazard for the personnel and the damage of the switchgear by the arc is very dependant of the arcing time. The thermal damage is substantially limited even with an arcing time beow 100 ms, compared with an arcing time of 1s. To limit the mechanical damage, caused by the high pressure from heated internal air, the arcing time has to be reduced below 10 ms. The normal time for opening pressure release flaps in arc-proof switchgear is 20 – 40 ms. This defines the maximum pressure, normally 0,5 to 1 bar gauge.

The AX1 switchgear has an integrated extremely fast acting “Arc Eliminator”, eliminating the arc within about 5 ms. An open arc is detected by an optical sensor and the device connects automatically the bus-bars to earth. The arc fault is converted to a normal short circuit, interrupted in the normal way. The switchgear is designed to withstand the short circuit forces and the very short arcing time does not cause any high pressure, nor any thermal damage at all. This also means, that there is no problem with poisonous gases in the switchgear room – special outlet channels to protect people from such gases are not needed. It also means, that different compartments are not needed to limit the arc damage to a certain part of the switchgear. The Arc Eliminator thus contributes to a very simple and safe design of the high voltage part of the switchgear, with air insulation instead of partitions with bushings.

The arc eliminator is a standard device in AX1, even though the design of the switchgear has been proven to withstand an internal arc for 1 s. The Arc Eliminator is possible to reset by opening after a closing operation.

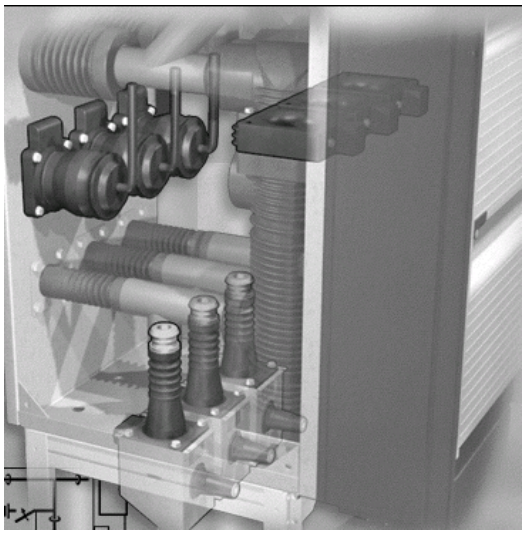
The arc eliminator is integrated in the busbar-support insulators



Operating sequence of active arc eliminator

2.5 Modern voltage and current sensors

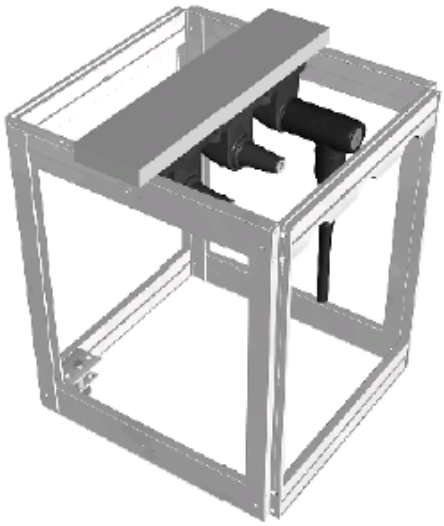
Rogowski coil current sensors are standard for protection measurement. These sensors cover the whole range of currents, from small normal current to short-circuit currents.
Conventional current transformers sometimes have to be reconnected to keep their sensibility at increased normal current of the feeder. This operation is not applicable for the Rogowski sensors, which also contributes to keep the main circuit compartment free from access during all its service.
For voltage measurements and indications resistive and capacitive voltage dividers are used. These have no iron and thus no ferrous-resonance problems.



3. Easy and fast installation on site

3.1 Pre-installation of cable compartments and cable connections

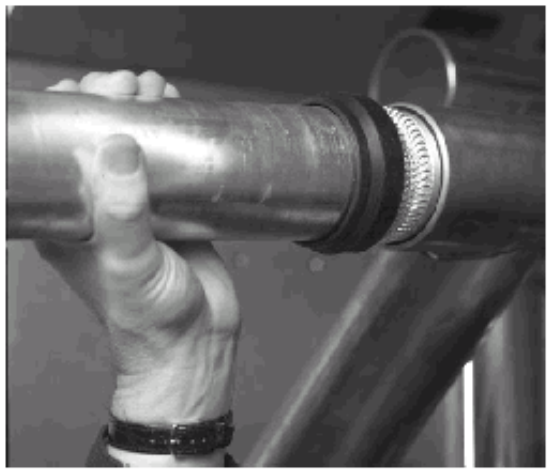
A conventional switchgear consists of a number of cubicles, mounted together in a row at site. After the switchgear installation the cables may be cut in proper lengths and connected inside the cubicles. The AX1 concepts offers an installation possibility the other way around.
The basic cubicle of AX1 is excluding the cable connection compartment. This is created by a framework of aluminium profiles, delivered as flat packs to the site. The framework may be fully mounted before the delivery of the cubicles. A simple tool is available, to indicate the precise location of the cable connection points of the cubicles. By this the pre-fabricated cable connections may be fully mounted in advance and later fast connected to the cubicles after their installation.



Lower framework with cable termination adapter.

3.2 Fast installation of cubicles with plug-in bus-bars and pre-tested wiring and software

The assembly of the cubicles on the plane pre-mounted framework is very simple. The plug-in type of bus-bar connections are easy to finalise and the auxiliary cable connections are also prepared with plug-in contacts.
The soft-ware and wiring has been tested in the factory before delivery. All this decreases the installation time of the switchgear substantially. Together with short delivery times, possible by the highly standardised concept, the total time from order to service may be very much reduced.



4. A compact air-insulated switchgear

The overall design of the main circuit compartment with the tubular bus-bars results in a very compact switchgear, comparable with gas-insulated designs, even though it is air-insulated.

A switchgear room needs space not only for the switchgear itself but also to provide a safe situation for personnel in the room. Different regulation specifies the necessary space for withdrawal of breakers and safe escape from the room in case of a severe fault. Normal swinging doors opens into the operating area and may severely danger the escape possibilities. So does circuit breaker trolleys, parked in front of the switchgear.

The AX1 concept gives access to important parts of circuit breakers, still inside the switchgear. It also has doors sliding vertically, never interfering with the operator area. The result is decreased total space requirements and increased personnel safety. The sliding doors also gives better survey and makes the work easier.

5. Designed with Environmental Care

An important issue for the design of new products is to minimise the environmental impact of the product for its whole life cycle. This means that the material shall be recyclable and the amount of energy needed for production and usage (service losses) shall be minimised. During the last decade different algorithms have been developed for this assessment, called Life Cycle Assessment, LCA. Every analyses is made with different focus and in different detail. It is therefore not possible to present one single value of the environmental load for a certain product. The calculation is however very useful to compare different design alternatives for a product, and assessments for alternative products are comparable, if they are made with the same conditions.

AX1 has been developed with LCA as a tool for the choice of material and technology. The overall compact solution contributes highly to the lower environmental load compared with conventional switchgear. As a result of the analyses insulated bus-bars have been avoided, to make the material recyclable. An interesting fact is that aluminium, used as profiles in both the front and the framework, has a low environmental impact compared with other metals, if it is recyclable, but a high impact if it is not recyclable. This is due to the relatively high amount of energy needed to make the metal from bauxite and the low amount of energy needed to melt aluminium at recycling. It is also obvious from an LCA, that the energy loss by the switchgear itself gives a substantial contribution to the total environmental load “from the cradle to the grave”. This gives an extra bonus for the high current carrying capability also for lower rated feeders, that is a result of the consistent standardisation of AX1 with a minimum of different variants of bars.