

ABB

The corporate
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review

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Special Report Medium-voltage products



Power and productivity
for a better world™



For over 25 years ABB has been developing and manufacturing vacuum interrupters for medium-voltage applications. State-of-the-art manufacturing processes, including immaculately clean rooms, ensure the highest standards of quality.



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Medium-voltage products



Bernhard Jucker
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Member of ABB Group Executive Committee



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Head of Medium Voltage Products business unit

Dear Reader,

Medium-voltage (MV) products play a key role in the distribution part of the power value chain, facilitating the “last mile” connect that brings electricity to billions of users around the world. ABB’s MV products tradition dates back to the 1920s with the introduction of the first MV switchgear manufactured by Brown Boveri. Today, ABB is a global market and technology leader in this space, with more than 30 production centers around the world and a sales and service network in over 100 countries.

ABB’s vast medium-voltage product portfolio serves utility, industry and infrastructure customers with the most reliable, efficient, safe and sustainable technologies. This includes solutions such as current conduction, control and interruption, electrical insulation, switching operations and network protection. Our products can be found in substations, industrial complexes, airports, skyscrapers and shopping malls, ships and oil platforms, railway lines, and major sports venues.

Technology and innovation are at the core of ABB’s medium-voltage product offering. As a case in point, we recently introduced UniGear Digital. This innovative product combines switching capability with a unique solution for protection, control, measurement and digital communication enabled by current and voltage sensors, which are integrated into each panel, alongside ABB’s multifunctional Relion IEDs that ensure an IEC-61850-based open communication protocol.

Eco-efficiency remains another key focus area of our R&D efforts to address the environmental challenge. For instance, ABB has developed a ring main unit (RMU) as compact as the traditional SF₆ insulated RMU but using dry air as an alternative. SafeRing Air provides a solution using an insulating gas that consists of atmospheric components, without enlarging the physical dimensions of the product, making it the most compact solution of its kind.

We are not only introducing new globally relevant products to serve customers but also developing products specific to the needs of different regions and countries around the world. As part of ABB’s “in country for country” strategy we locate manufacturing and R&D centers in proximity to our markets so we can be closer to our customers. Recently launched products for India, China and the United States bear testimony to this approach.

We also continue to develop innovative technologies that are enabling grids to get smarter by facilitating network automation and distribution management and addressing areas like fault management, outage response, reporting and network planning. We also offer solutions for refurbishment and maintenance asset optimization.

In addition to serving the needs of our customers directly, we leverage high-value partnerships with distributors, original equipment manufacturers (OEMs) and engineering, procurement and construction companies (EPCs), and our extensive worldwide channel partner network helps us to penetrate local markets and serve a vast customer base with a comprehensive product portfolio.

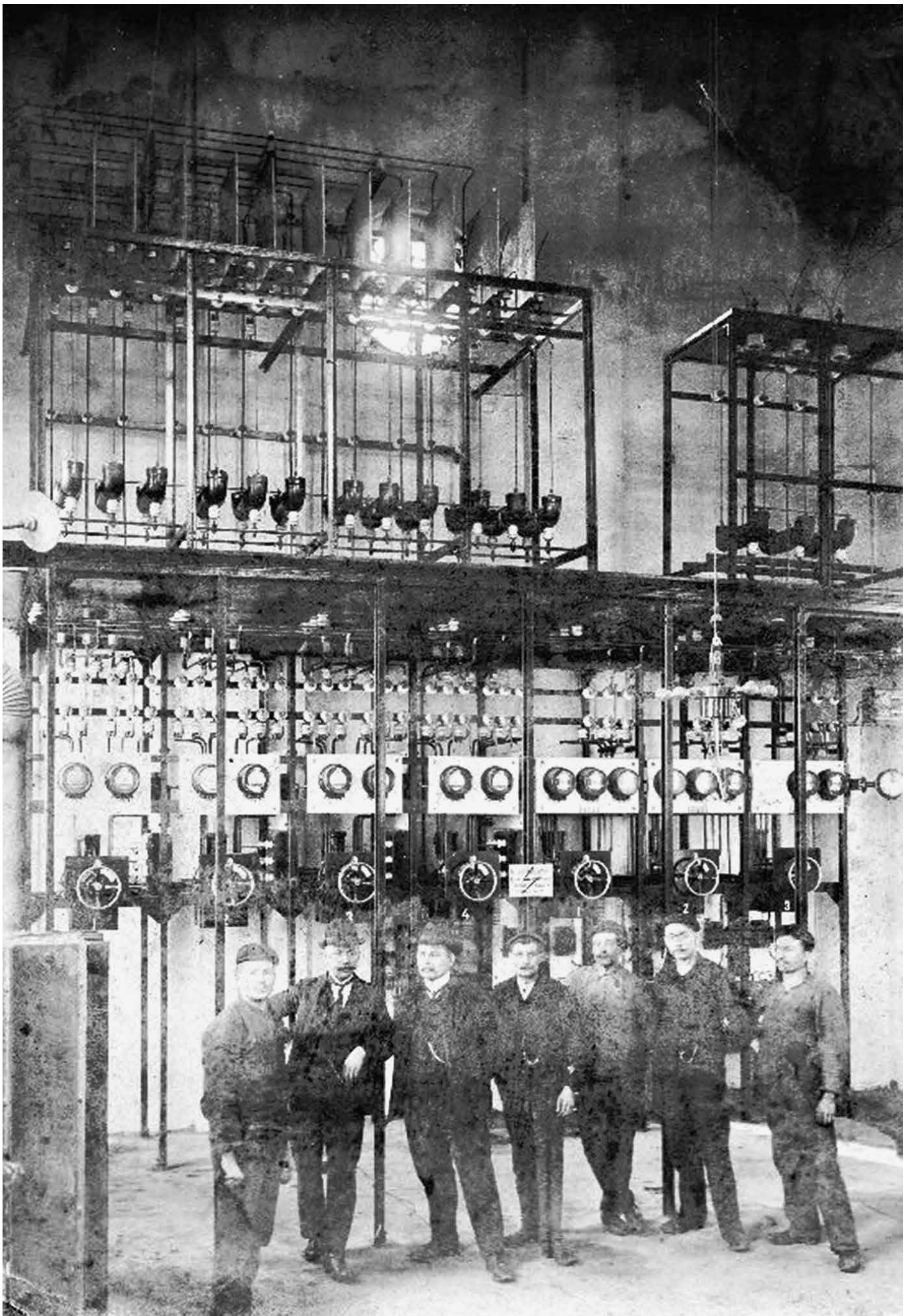
We hope you enjoy this special edition of *ABB Review*, which sheds light on the world of power distribution from a medium-voltage-products perspective. We bring you some of our recent innovations and developing technologies that are shaping evolving power networks and elaborate on how we are helping our customers address the challenge of providing safe, reliable and adequate electricity all over the world.

Happy reading!

Bernhard Jucker

Bruno Melles





Distribution evolution

Medium-voltage distribution technology is a key part of the power network

GERHARD SALGE – It is well over a century since the so-called Current Wars that pitted Edison’s established direct current (DC) distribution technology against the new alternating current (AC) approach championed by, among others, Westinghouse (later to be part of the ABB family). Initially, DC was the standard method of medium-voltage (MV) power distribution in the United States but, as time went on, AC technology caught up with and then overtook DC: Workable AC motors were developed; AC transmission lines were shown to be much more efficient; and AC transformers were invented that allowed simple voltage step-up and step-down – the Achilles heel of DC. In the 120 years since the ousting of DC, AC technology has evolved to such an extent that today’s MV distribution network would be unrecognizable to the early pioneers: Numerous sophisticated technologies are now employed for current conduction, electrical insulation, switching operations, protection, control and interruption. The modern MV distribution product provider must be master of all these.

Title picture

ABB has over a century of experience in MV distribution technology. The photo shows ABB (then Brown Boveri) MV switchgear from the 1920s.

Though DC technology is experiencing a resurgence in specific applications like data centers, AC is now the weapon of choice for distributing electrical power. The last remnants of DC hung on until the middle of the last century – the New Yorker Hotel, for example, converted fully to AC only in the late 1960s. (Ironically, it was in this very hotel that the AC pioneer Nikola Tesla spent the last years of his life.)

With the realization last century of the first high-voltage AC transmission lines, today’s familiar power network began to emerge. In the vicinity of the user, the voltage is stepped down (transformed) from the high voltages produced by the generators to medium-voltage levels (1 kV to 52 kV). Large industrial users may consume power directly at these levels; households require further stepping-down to a few hundred volts.

For it to be reliable and safe, a modern AC MV distribution network relies on multiple technologies. These cover aspects such as current conduction, electrical insulation, switching operations, and protection, control and interruption capabilities during any type of network failure. This entails the use of:

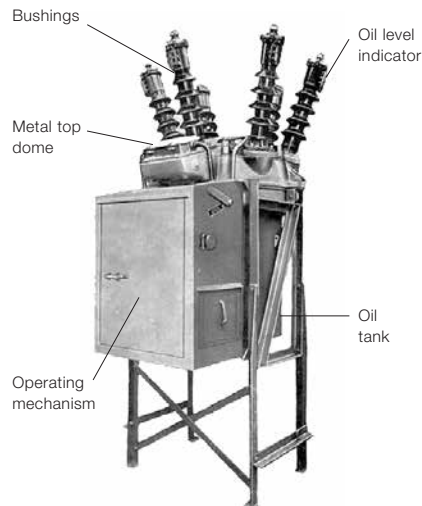
- Switching elements for normal situations and any type of fault condition.
- Protection and control equipment to supervise the network and trigger appropriate switching elements in normal and fault situations.

In the 120 years since the ousting of DC, AC technology has evolved to such an extent that today’s MV distribution network would be unrecognizable to the early pioneers.

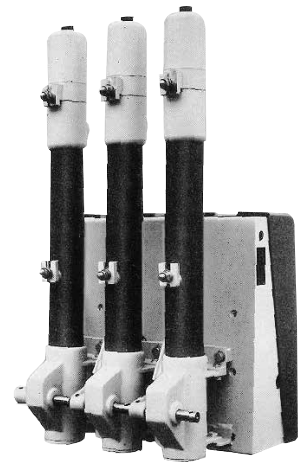
- Measurement equipment for voltage and current.
- Switchgear for safe incorporation of all switching, protection, control and measurement equipment.

Gas-insulated switchgear using SF₆ was introduced to the market in the early 1980s by ABB as a three-phase design.

1 Bulk oil circuit breaker



2 Calor Emag minimum oil CB OD4 for 20 kV (1976)



Switchgear history and development

The first installations of MV-like switchgear are mentioned in the literature in 1900. In the beginning, designs were very simple and focused purely on technical functionality; safety requirements and footprint were of little interest → [title picture](#).

With growing operational experience, switchgear design and optimization parameters changed significantly. For instance, electrically live parts (at MV potential) were encapsulated in steel to shield operators from live parts and hazards arising from equipment faults. This evolved into today's standard arc-resistant switchgear. In a further significant step forward, porcelain (later epoxy) insulators were brought into play.

One aspect that has changed little is the insulation gas: Today, the majority of switchgear worldwide is still air-insulated. However, gas-insulated switchgear (GIS) using SF₆ (sulfur hexafluoride) was introduced to the market in the early 1980s by ABB as a three-phase design and by

state-of-the art technology is now used by the majority of producers worldwide.

Today's air-insulated switchgear (AIS) and GIS are highly optimized with respect to functionality, operator safety, reliability and footprint. The choice between AIS and GIS depends on a customer's specific requirements.

MV switching equipment

In the beginning, the preferred MV current interruption technology was based on the air-blast technique. Air-blast circuit breakers (CBs) used either axially or radially blown air streams to deform and cool or stretch, and thus quench, the arc. In a further enhancement, arc chutes were used to split the arc up in order to increase the arc voltage and make it easier to extinguish. This type of breaker needed air compression up to 100 bar and the associated compressors, high-pressure containers, fast valves and pipes.

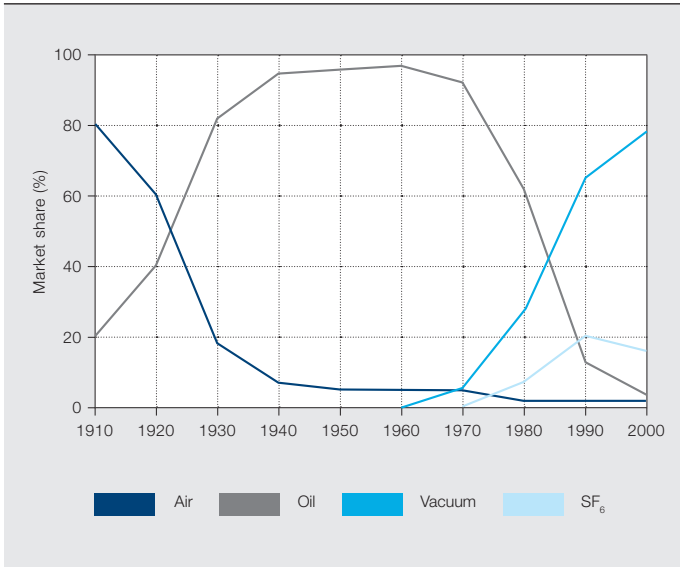
In a second technology step, oil breakers started to be used in MV applications.

The latest, and today's dominant, MV interruption technology is based on vacuum techniques.

Siemens as single-phase design. The three-phase approach is more compact than the single-phase concept and this

The first generation of these – bulk oil breakers – consisted of a steel tank filled with oil from which the arc was drawn and interrupted between two simple contacts → [1](#). These

devices had very limited interruption capabilities (approximately 15 kV and 200 A) and high explosion risk. As a next step,



tubes were placed around the interrupter contacts, thus helping to shape the oil flow. With this development, higher currents (up to 50 kA) could be interrupted. As a side effect, the amount of oil within the breaker was significantly reduced and thus was born the minimum oil breaker, which was used until the 1970s with great success → 2.

The next technology generation of MV circuit breakers was based on SF₆. After the first SF₆ circuit breaker patent was filed by Westinghouse in 1951 it took approximately 10 more years for the first breakers to enter the market. The interrupting technology started with two voluminous pressure systems requiring a gas reservoir at high pressure, similar to air-blast breakers. Then puffer breakers followed (around 1970) where the operating mechanism produced the high SF₆ pressure during opening via a moving piston. Finally, in the 1980s, the self-blast breaker was introduced, where the blast pressure was extracted from the energy of the arc itself, making the operating mechanism much more efficient.

The latest, and today's dominant, MV interruption technology is based on vacuum techniques → 3–4. To make this approach possible, multiple constituent technologies, namely Al₂O₃ ceramics, oxygen-free copper, appropriate clean-room manufacturing, advanced brazing technologies and copper-chromium contact technology had to reach mature industrial status. In 1982, ABB introduced an interrupter, called VC1 (24 kV/25 kA), that used this technology. The produc-

tion technology developed rapidly from manual welding of flanges and evacuation of the vacuum tube by diffusion pumps and pinch-off, to one-shot braz-

The new generation of ABB's UniGear switchgear (UniGear Digital) fully exploits IEC 61850 to bring more flexibility and value to the switchgear customer

ing technique in a high-temperature furnace evacuated by turbo-molecular pumps. Today, ABB uses spiral-shape contact technology to make devices with short-circuit ratings of up to 63 kA.

Protection and control

ABB and its predecessors ASEA, BBC, Westinghouse, ITE and Strömberg have all played an important role in the evolution of MV protection and control technology over the past few decades by developing techniques to isolate malfunctioning units and minimize power outages. Early units were merely single-function electromechanical relays and solid-state (static) relays. Different con-



4a Circuit breaker VD4 for indoor applications



4b Circuit breaker OVB-VBF for outdoor applications

struction types satisfied different electromechanical needs and the basic principles exploited were electromagnetic attraction, electromagnetic induction and solid-state electronics.

During the 1970s, significant hardware and software progress led to the first commercially available microprocessor-based relay (1979). The digital relays found on the market in the 1980s were relays with very basic functions, hybrid relays combining analog and digital techniques, and relays offering economical but barely adequate performance. Further progress led to multifunction relays in the late 1980s. This led to significantly enhanced network protection and control.

ABB took a leading role in the standardization work that paved the way for the following generations of relays. For example, the IEC 61850 standard, which represents the state-of-the-art for transmission and distribution relays, was developed and harmonized with major contributions from ABB. Subsequently, in 2007, the first ABB Relion relay for distribution applications capable of communicating in native IEC 61850 was launched → 5. Today, IEC 61850 ensures the future of relay communication and provides substantial advantages during switchgear design, installation and operation. The new generation of ABB's UniGear switchgear (UniGear Digital) fully exploits this technology to bring more flexibility and value to the switchgear customer → 6.



The relay has evolved from a simple protection device into an intelligent electronic device (IED) that is able to perform control, automation and communication functionalities. Associated software and hardware platforms are configurable via software and are integrated into distribution management systems (DMSs).

Measuring and sensing

The technology for measuring voltage and current has also undergone a revolution. The very first instrument transformers were just smaller versions of oil-paper-insulated power transformers, consisting of an iron core, primary and secondary windings, insulating oil and porcelain bushings. To get rid of the oil and to become more compact, cast resins have been used since the early 1960s. Over the decades, ABB and its predecessors contributed significantly to indoor as well as outdoor instrument transformer progress. Westinghouse and ABB brought aliphatic epoxy blends for indoor applications to the market. In 2005, ABB was the first manufacturer to introduce a hydrophobic cycloaliphatic epoxy for outdoor applications.

Today, the design and technology of the current or voltage measurement are highly dependent on the device that is connected and which additional functionalities the instrument transformer has to deliver. In this respect, sensors (some-

times also called electronic instrument transformers or low-power standalone sensors) are becoming more and more popular. Current measurement is usually based on the Rogowski principle, while voltage sensing can be either resistive or capacitive. Sensors can offer some significant technical advantages in terms of linearity, weight, safety (no ferroresonance) and space saving. In combination with the latest generation of IEDs, sensors offer a very interesting technological alternative, with additional value for the customer, to conventional instrument transformers.

Main features

Four main features characterize MV switchgear and substations: safety, reliability, environmental friendliness and intelligence. Technological advances are constantly improving operator safety – for example, ultrafast earthing switches (UFESs) working in combination with fast protection relays; ferroresonance-free sensors; optimized switchgear design that uses advanced simulation techniques; and new materials that have excellent flammability behavior. Optimized switchgear panel design also makes operation safer. Reliability is increased by high-performance circuit breakers and equipment that is produced in high-quality manufacturing processes. New materials are environmentally friendly and the latest IED design enables advanced protection,

control, communication and equipment supervision functionality in combination with optimized human-machine interfaces. This *ABB Review Special Report* highlights numerous examples of the future of medium-voltage technology.

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Reference

- [1] Falkingham, G. Montillet (2004), "A History of Fifty Years of Vacuum Interrupter Development," retrieved from: <http://www.vil.org.uk/USBpapers/VIDevelopment/PESGM2004-000429.pdf> (2014, January 1).



Switching gears

Moving to smart switch-gear for primary and secondary substations

VINCENZO BALZANO, MARTIN CELKO – Medium-voltage (MV) distribution systems are undergoing a revolution: Gone are the days when they merely distributed power of consistent quality from some far-off generator and performed basic switching and protection duties. Now, intermittent local generators, such as wind and solar sources, present a more complex energy flow for the distribution equipment to handle. Further, there are heightened quality and reliability expectations from operators and consumers. This puts the onus on utilities to make sure their often aging grids become safer, smarter, more efficient, more reliable, and more environmentally friendly, and in addition, easier to engineer, install and operate. This is why MV distribution networks are becoming “smart.” To address the demand for smart switchgear, ABB has developed the UniGear Digital concept for primary substations and the SafeRing, SafePlus and UniSec products for secondary substations.



Major changes are running through the power industry: On top of industry-mandated indices like the system average interruption duration index (SAIDI) and system average interruption frequency index (SAIFI), many states are introducing a range of other grid efficiency regulations. Further, the energy generator and consumer landscape is becoming more mixed and more sophisticated with intermittent generators like solar and wind sources jostling for grid access and major new

to the genesis of the so-called smart grid. At the power distribution level, the smart grid offers an intelligent way to approach grid efficiency and reliability, and provides a solid foundation for the automation, and remote monitoring and control of switching. But smart distribution needs smart products, at both the primary and secondary substation levels.

ABB UniGear Digital

ABB's UniGear Digital is not just the next version of an established product.

Rather, it is a new concept – a new way of going about MV switchgear. The concept combines well-proven switchgear design with an innovative approach to protection, control, measurement and digital communication. It is based on an optimized integration of current and

The smart grid offers an intelligent way to approach grid efficiency and reliability, and provides a solid foundation for the automation, and remote monitoring and control of switching.

consumers, like data centers, placing stringent demands on power providers.

All this is happening to an infrastructure that has changed little since its inception in the early 1900s. This situation has led

voltage sensors into MV switchgear, combined with the latest intelligent electronic devices (IEDs) and IEC 61850 communication. The concept is embodied in the UniGear ZS1, an ABB MV air-insulated switchgear for primary substations.

Title picture

Improved levels of automation and communication in substations give central operators, like those pictured, the ability to optimize grid operation.



This switchgear is produced locally around the world and more than 200,000 UniGear panels have already been installed in more than 100 countries. The UniGear ZS1 is used in demanding locations such as offshore platforms, container or cruise ships and mines, as well as in the more common applications, like utility substations, power plants, chemical plants, etc. → 1.

Lower cost and easier setup

With the UniGear Digital concept, “one size fits all” so there is no need to change primary MV components, for example instrument transformers, if the load changes. This saves time and money during project planning and execution.

Energy losses during operation are lower with the UniGear Digital than with equivalent devices: Instrument transformer losses are eliminated and this can save around 250 MWh over the 30-year life of a typical substation. This represents a reduction of about 150t in CO₂ emissions.

Costs are also reduced because the UniGear Digital has fewer live parts, so outages are less frequent and troubleshooting effort is reduced. UniGear Digital takes up less space in the substation – a real cost-saver where real estate is expensive or limited.

Setup is easier too. The streamlined setup procedure eliminates the necessity, in many cases, to define details such as relay parameters, current transformer

(CT) data and voltage transformer (VT) data. CT/VT data does not have to be calculated, checked and approved, and last-minute changes can be realized in the IED logic. IEDs are perfectly suited to protection, control, measurement and supervision duties concerning utility and industrial power distribution – including radial, looped and meshed networks.

Using the IEC 61850 standard, the international standard for electrical system automation, further simplifies things. Protection and control IEDs publish signals for interlocking, blocking and tripping between panels via horizontal GOOSE communication. GOOSE (generic object-oriented substation events) – defined under the IEC 61850 standard – is a control model mechanism in which any format of data (status, value) is grouped into a data set and transmitted. GOOSE communication is becoming popular in substations as it offers simplicity, functionality, flexibility, easy scalability, improved diagnostics and faster performance.

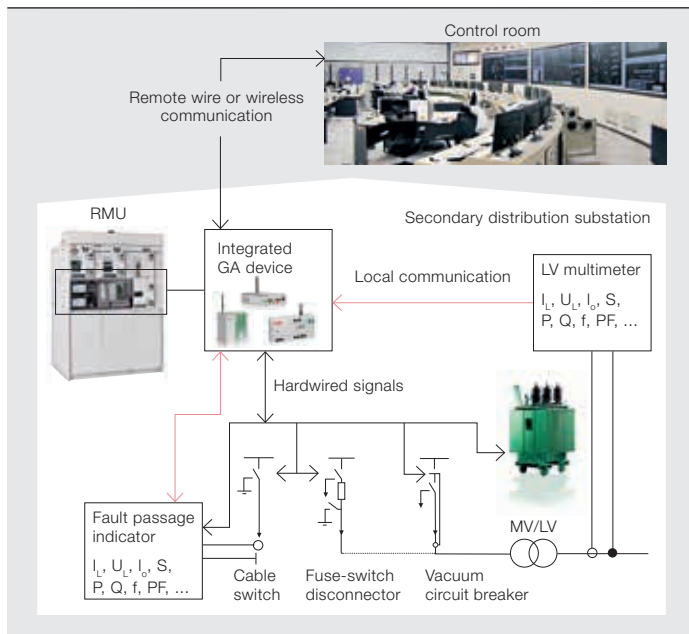
The IEC 61850-9-2 LE process bus is also used by IEDs for transmitting sampled measured values (SMVs). UniGear Digital uses it for sharing busbar voltages, for example.

Secondary substation automation products

Two elements are essential to enable the smart grid at the secondary substation level: automation of the secondary substation switchgear itself and the ability to

UniGear Digital combines well-proven switchgear design with an innovative approach to protection, control, measurement and digital communication.

4 Whole system overview



5 Typical automation level features

Feature	Level name:			
	Monitoring	Control	Measurement	Protection
MV network switches position monitoring	x	x	x	x
MV network fault monitoring (including fault direction)	x	x	x	x
Distribution transformer feeders fault monitoring	x	x	x	x
MV network switches position control	n/a	x	x	x
MV network analog values measurement	n/a	n/a	x	x
Protection functions (including autorecloser)	n/a	n/a	n/a	x
MV network faults indication reset command	o	o	o	o
LV network analog values measurement	o	o	o	o
Distribution transformer feeders emergency trip command	o	o	o	o
Customer-specific signals (LV network faults, water intrusion, etc.)	x	x	x	x

x - available o - option n/a - not available/applicable

Energy losses during operation are lower with the UniGear Digital than with equivalent devices.

communicate with the remote SCADA (supervisory control and data acquisition) system. ABB has products that address these: gas-insulated SafeRing and Safe-Plus ring main units (RMUs) and UniSec air-insulated switchgear (AIS).

SafeRing and SafePlus RMU gas-insulated switchgear (GIS) is designed with flexibility and compactness in mind. Each consists of a completely sealed system with a stainless steel tank containing all the live parts. This virtually maintenance-free system ensures a high level of reliability and personnel safety → 2.

UniSec air-insulated switchgear is based on a highly flexible, modular concept that can be readily configured to meet the specific needs of each application. UniSec is used in secondary substations where normal environmental conditions prevail, no

Secondary substation automation

To enable automation, MV switchgear is equipped with an advanced grid automation (GA) controller. This device collects data available within the substation, puts it into a standard communication protocol and transfers it to the remote control center for evaluation → 4.

This improved level of automation and communication in substations gives the remote operator the ability to adjust different operations in order to:

- Provide high-quality power at all times
- Reduce energy transport losses
- Enhance network stability
- Avoid (or shorten) outages
- Avoid overloading network components
- Improve maintenance planning
- Enhance field crew efficiency
- Optimize asset management

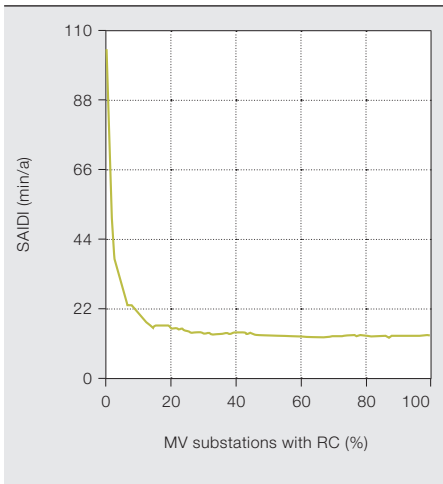
The streamlined setup procedure eliminates the necessity, in many cases, to define details such as CT/VT data, and last minute changes can be realized in the IED logic.

Different levels of remote automation are available for ABB secondary switchgear and the user can select the one that best suits his needs → 5. Each level comes with a predefined IED standard package, which, in some

severe space restrictions apply and complex configurations and accessories – with, for example, MV instrument transformers or surge arresters – are required → 3.

cases, can even be integrated into the MV switchgear, thus eliminating the need for additional mounting space. Customization of these standard packages is

6 Nonavailability (SAIDI) of a network against number of MV substations equipped with remote control (RC) technology



8 Smart grid in Rome

Acea Distribution, an Italian utility, is committed to making electricity distribution in the MV and LV networks more intelligent, with the aim of making Rome a smarter city. Acea started with a pilot project – one of eight Italian pilot projects approved and partially financed by the Authority for Electricity and Gas. For Acea, ABB is a partner in this venture, rather than just a supplier – indeed, a cooperation agreement was recently signed in this regard.

In the experimentation phase, ABB provided UniSec switchgear, current sensors, voltage sensors and IEDs for the secondary substations. The logic employed is based on IEC 61850 protocol. Inter-substation and control system communication use GOOSE, over a private wireless network.

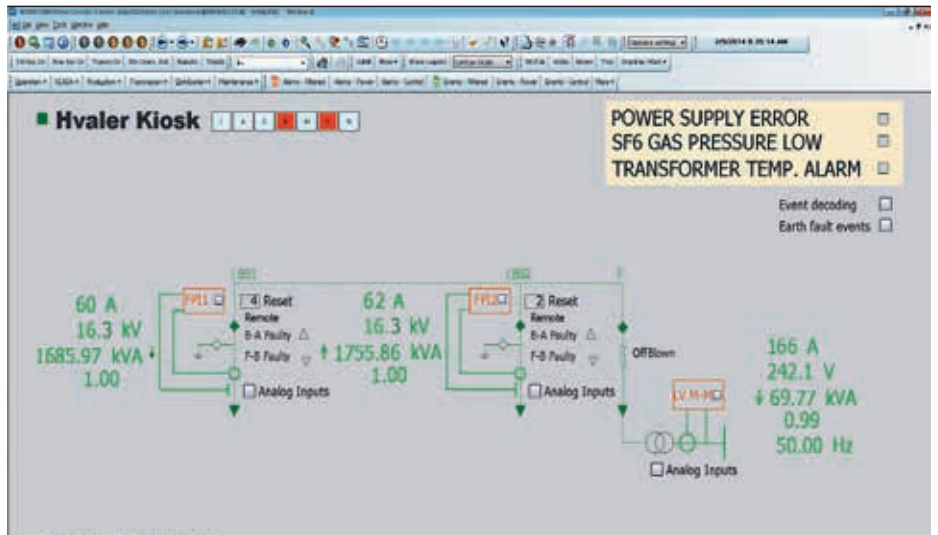
The system is installed on a new portion of the Rome electrical distribution grid and will allow ACEA to substantially reduce the number and average duration of service interruptions, with a consequent reduction in restoration times and penalties.

also possible. All standard packages include:

- Power supply backup source for IEDs (24V DC batteries)
- Wired and/or wireless (GSM/GPRS) communication interfaces
- Preconfigured IEC 60870-5-104 remote protocol signals

All IEDs installed within the switchgear or kiosk are factory preconfigured based on the standard package specification. The communication system details (IP addresses, access point name, SIM card PIN, etc.) and MV network parameters (fault pickup current, fault current pickup time, etc.) are usually configured on-site.

7 SCADA screenshot



9 Norwegian Smart Grid Centre

Two years ago, the island municipality of Hvaler in Østfold, Norway, was chosen to be the test laboratory for smart technology in MV and low-voltage (LV) distribution networks. This project is called DeVID (Demonstration and Verification of Intelligent Distribution networks) and is part of the Norwegian Smart Grid Centre.

The archipelago has a mix of homes that are occupied year-round, vacation condominiums, and commercial activity that provide the opportunity to study different electricity usage profiles.

Hvaler has 3,000 houses and 4,300 condominiums. The population increases from 4,000 in winter to 30,000 in summer, presenting a challenge for the entire infrastructure, including the power network.

ABB is one of several participants in DeVID and ABB's contribution is a Magnum compact secondary substation (CSS) with a SafeRing 24 kV switchgear that allows the local utility, Fredrikstad Energi, to locate any faults quickly and to monitor power quality and load in this part of the network.

The CSS is monitored via ABB's Network Manager SCADA, part of the company's Ventyx (enterprise) software portfolio; communication between SCADA and the CSS is via GSM. The two load break switches in the RMU can be controlled from the SCADA system and approximately 200 measurement parameters are monitored → 7.

GA effectiveness

For a quick evaluation of the effectiveness of a particular GA solution, ABB uses an activity-based costing (ABC) calculation tool developed in cooperation with the National Technical University in Aachen, Germany. This allows calculation of, for example, the impact of a SafeRing installation and standard GA package on SAIDI → 6.

Smart switchgear is already making a big impression → 8–9. The smart grid is still in its infancy. Renewable sources, distributed generation and an increasingly complex and demanding network of power consumers are just some

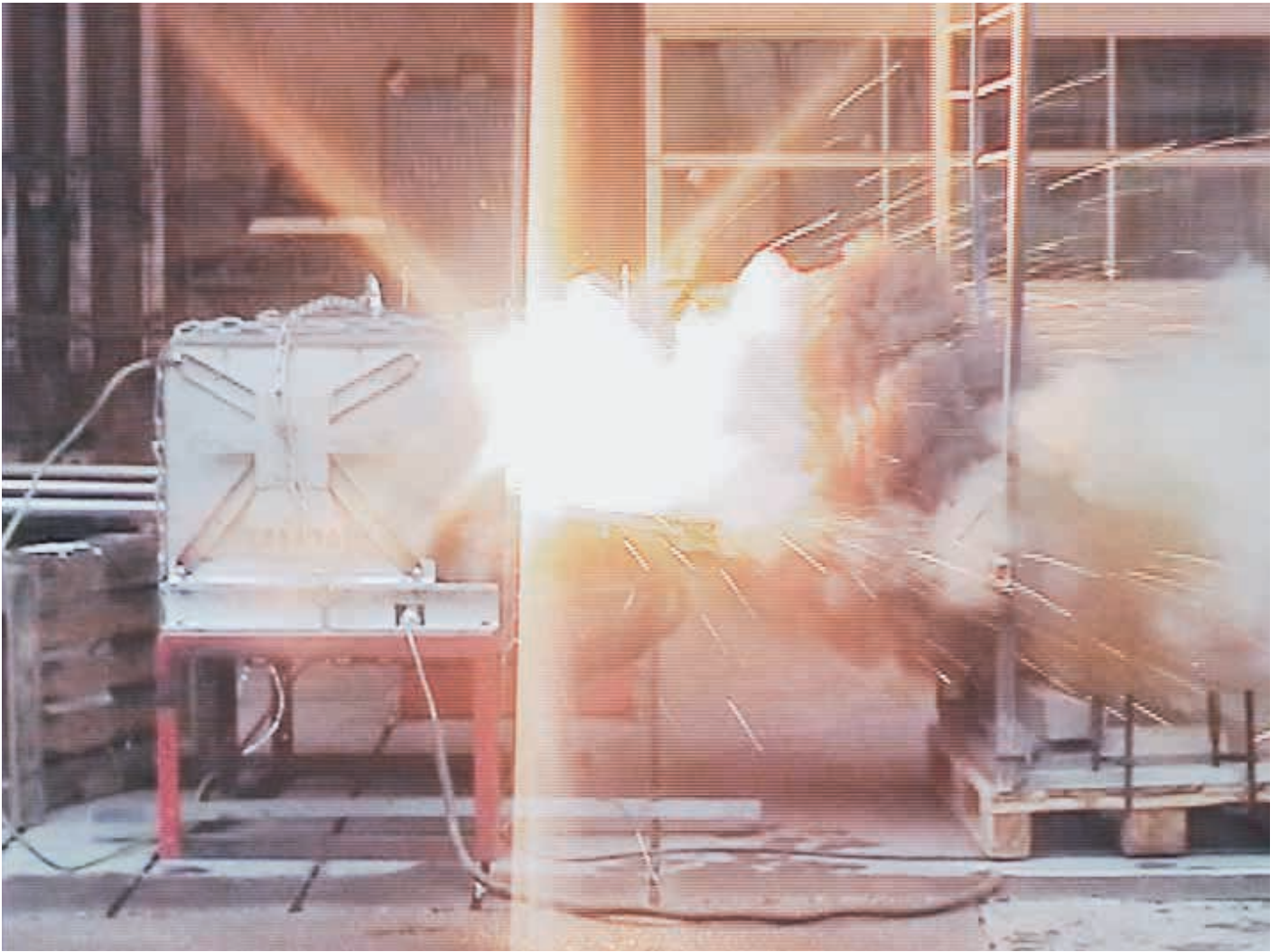
of the factors that will drive future product development in smart distribution switchgear.

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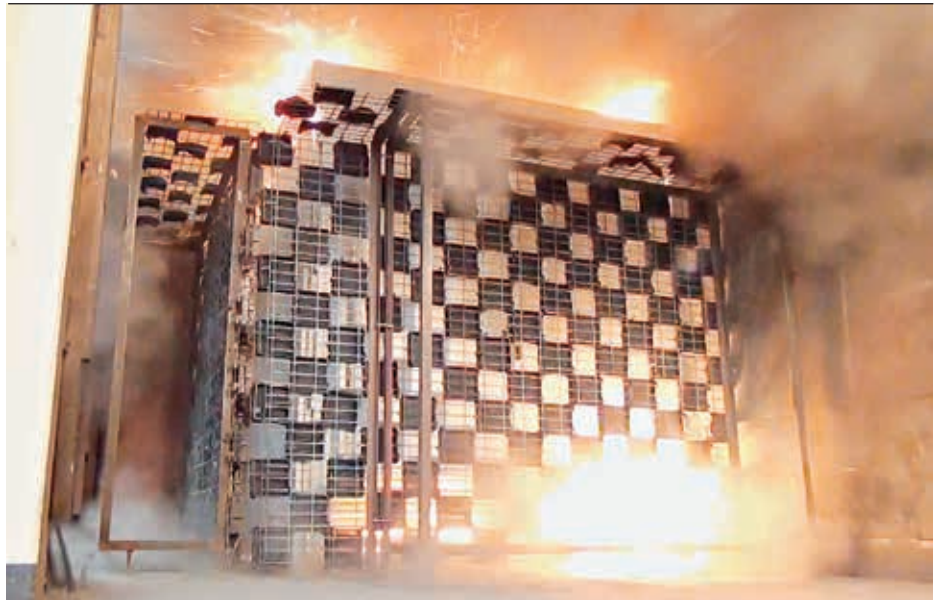
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Feeling the pressure

Simulating pressure rise in switchgear installation rooms

EDGAR DULLNI, PAWEL WOJCIK, TOMASZ BLESZYNSKI – An internal arc fault is an unintentional discharge of electrical energy in switchgear. During the fault, short-circuit currents flow between phases and to ground. The arc heats the filling gas in the switchgear enclosure – either SF₆ or air, resulting in pressure rise. The incidence of a fault is very rare, but when it happens it may seriously damage the electrical equipment and the building and may even endanger personnel. It is only possible to evaluate the pressure rise in a building by calculation. Nevertheless, calculations should be substantiated by special tests allowing the measurement of external pressure rise. ABB has developed a calculation program that is easy to use by developers of switchgear and civil construction engineers.



Pressure rises stress switchgear enclosures mechanically. In order to avoid rupture, a relief device opens at defined pressure. The fault arc produces hot gas, which has to be directed in a controlled manner into the environment. Most often, exhaust channels are placed on top of the switchgear. These channels often possess a hatch or absorber at the end, where the hot gas is cooled down before it leaves the channel.

Standards eg, IEC 62271-200 [1] require switchgear to be safe for operating personnel, even if an internal arc occurs → 1. Type tests not only verify that the switchgear enclosure withstands the pressure, but also prove that hot gases are directed away from personnel. IEC 61936-1 [2]

Title picture

Image captured from a high speed video showing the controlled exhaust of hot gasses from medium voltage switchgear during an internal arc test. ABB software calculates the observed pressure development inside the switchgear and in the installation room.

requires that the building design shall take into account the pressure rise due to these exhaust gases. Switchgear arc fault tests do not cover this aspect, since the installation room is simulated by two perpendicular walls and ceiling, which do not present a gas-tight room allowing room pressure measurement. Therefore it is only possible to evaluate the pressure rise in a building by calculation. Another application for the calculation program is to simulate the pressure rise for different filling gases, ie, SF₆ and air. For validation, tests were conducted together with RWTH Aachen and TÜV Nord Systems GmbH.

Equations in the calculation program

Gas pressure in an enclosure depends on gas temperature, in accordance with the ideal gas law. Mass balance equations consider mass flow out of the enclosure. Compartments are represented by their effective volumes (components subtracted) and pressure relief areas in between. Gas properties such as the specific heat capacities are independent of temperature and uniform all over the volume [3].

Some fraction – called thermal transfer coefficient k_p – of the fault arc power heats up the gas in the arc compartment:

$$Q_i = k_p \cdot W_{el}$$

The electrical arc power is evaluated from measured currents and phase-to-ground voltages:

$$W_{el} = (u_R \cdot i_R + u_S \cdot i_S + u_T \cdot i_T) t$$

The measured voltages are not necessarily identical to the arc voltage, because a three-phase arc can burn between two phase conductors, but also to the grounded enclosure. The pressure calculation tool either imports measured phase-to-ground voltages from a formatted data file or applies an empirical average phase-to-ground voltage.

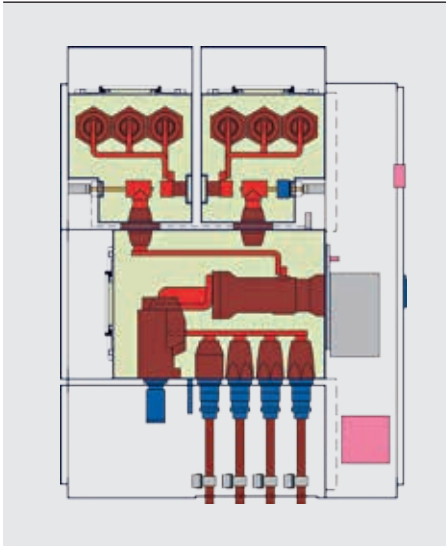
All time-dependent quantities in the Internal Arc Tool (IAT) are regarded before and after a time step Δt . The following equation shows the mass flow out of the arc compartment into the exhaust compartment:

$$\Delta m_{12} = \alpha_{12} \cdot \rho_{12} \cdot w_{12} \cdot A_{12} \cdot \Delta t$$

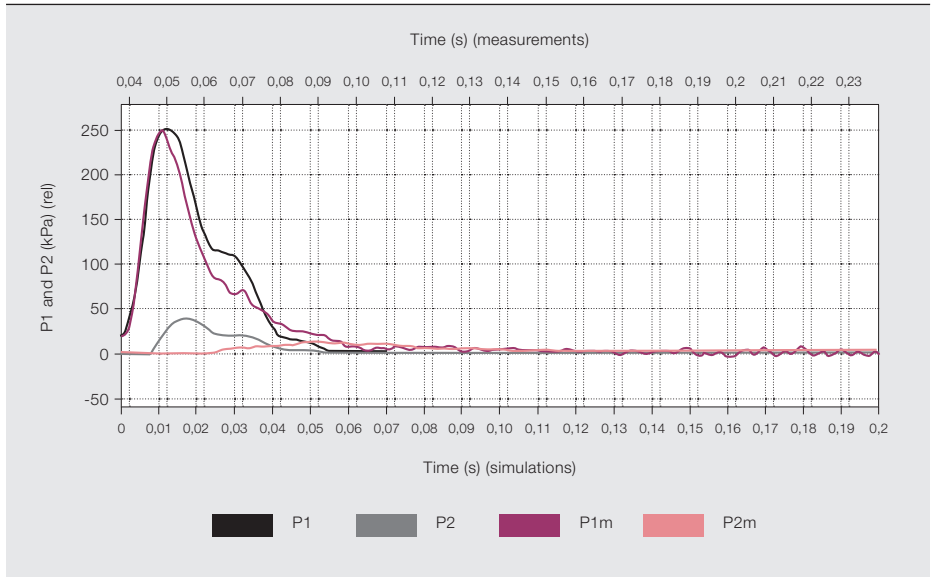
α_{12} is the efficiency of a relief device with area A_{12} and considers the contraction of gas flow through an opening with sharp edges (0.7 to 1.0), but also the flow reduction due to eg, a mesh or absorber. When the relief device opens, the mass Δm_{12} escapes from the volume per time step. ρ_{12} and w_{12} stand for gas density and gas velocity inside the opening according to Bernoulli's law [3]. This mathematical approach allows for the calculation of the pressure rise in all involved volumes.

The accuracy of the calculation is limited by the applied simplifications. Because of the assumption of constant specific heat capacities, dissociation of gas molecules into fragments is not considered. This starts at 6,000K in air and 2,000K in SF₆. However, agreement with test results is obtained also for higher gas temperatures.

2 Cross-section of ABB switchgear type ZX2 with arc initiated in busbar compartment and pressure relief into the channel on top

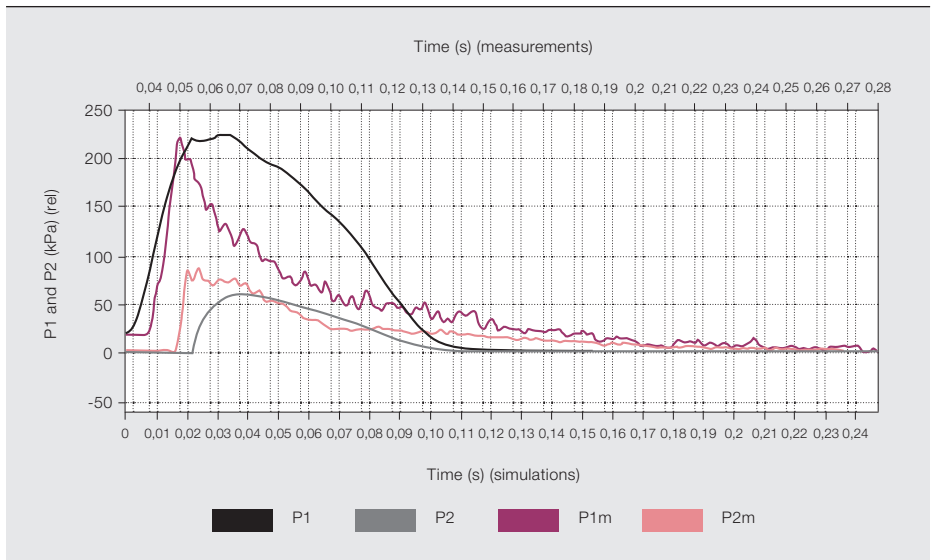


3 Comparison of calculated and measured pressure developments for an internal arc in ZX2 using air as filling gas (38 kA)



Type tests not only verify that the switchgear enclosure withstands the pressure, but also prove that hot gases are directed away from personnel.

4 Comparison of calculated and measured pressure developments for an internal arc in ZX2 using SF₆ as filling gas (35 kA)



If a considerable amount of gas flows out of the switchgear compartment, fewer and fewer gas molecules remain in it. If the heating fraction k_p of the arc energy stays constant in time, an ever increasing gas temperature would result, exceeding known arc temperatures of 20,000 K by far. This is not realistic and also generates numerical instabilities. To avoid this, the k_p is taken as density dependent [4]. This modification allows the extension of the calculation to longer fault durations and for calculating the pressure rise in the installation room.

Tool description

The proposed methodology was successfully implemented in the IAT simulation software at ABB's Simulation Tools Center (STC).¹

The tool consists of two parts: graphical user interface (GUI) and solver. The solver was developed in Python and the user interface in Java. The main features delivered by the IAT GUI are:

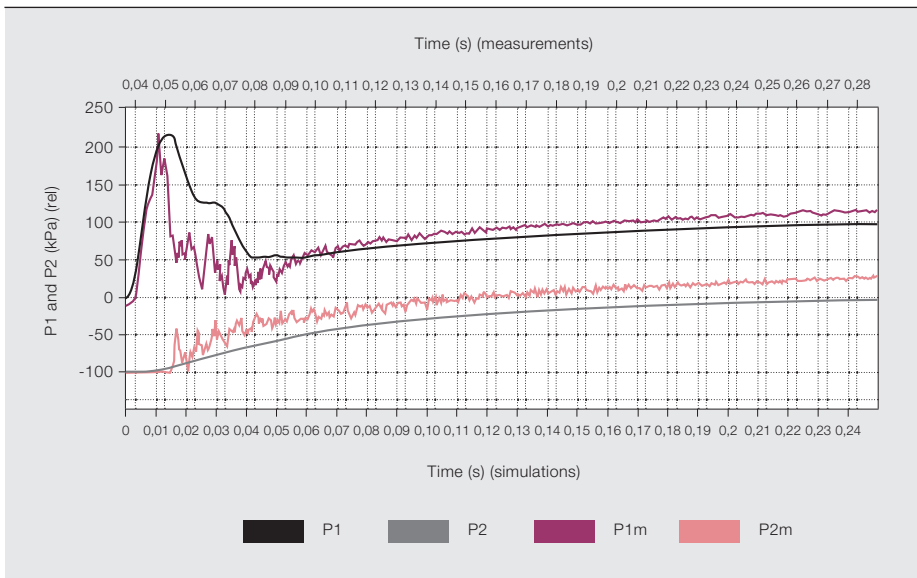
- 1) Set up model parameters
- 2) Run solver
- 3) Visualize results
- 4) Create report

Model parameters can be set directly or can be selected from a drop-down list and each parameter is validated. When the model is ready, the user is able to start the simulation. They are guided through the simulation setup by a simple wizard. Simulation time takes less than

Footnote

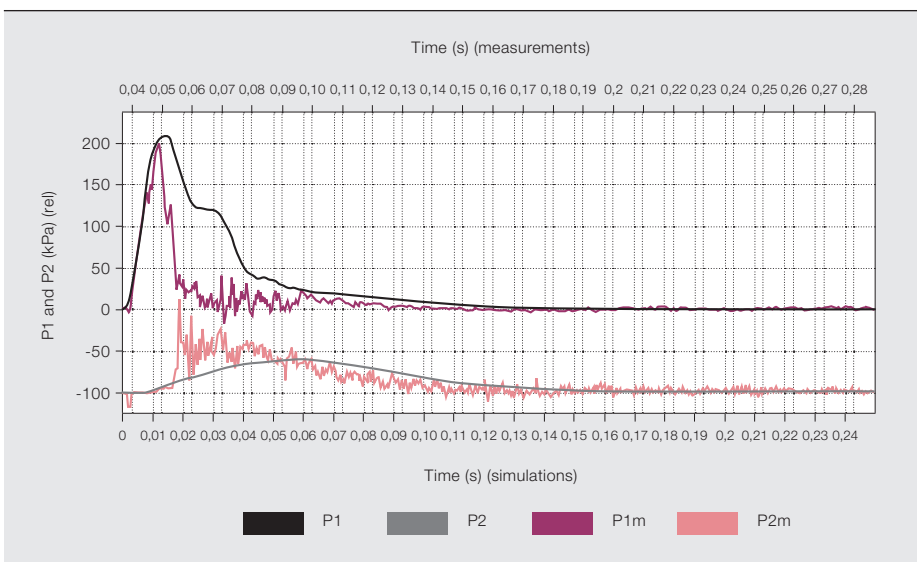
¹ See also → 7 on page 71 of ABB Review 3/2013.

5 Comparison of calculated and measured pressure developments for an arc in a test arrangement using an 8 m³ closed container (20 kA)



Simulation time takes less than 10 s for a maximum arc duration of 1 s on a laptop.

6 Pressure developments as in → 5 with 0.3 m² relief opening (20 kA)



10 s for a maximum arc duration of 1 s on a laptop. The calculations are performed with a constant simulation time step of 0.05 ms. For comparison with tests, measurement data in proper format can be imported.

The following characteristics are drawn:

- 1) Pressures vs. time
- 2) Phase currents vs. time
- 3) Phase to ground voltages vs. time
- 4) Integrated arc power vs. time

Plots can be dynamically modified and no additional editor for visualization is needed. Examples are shown in → 3 – 9.

Additionally, text files with simulation parameters (selected input and output values) and result data are generated.

Comparison of results

The IAT results were compared with results from tests obtained with ABB switchgear and specially designed experiments.

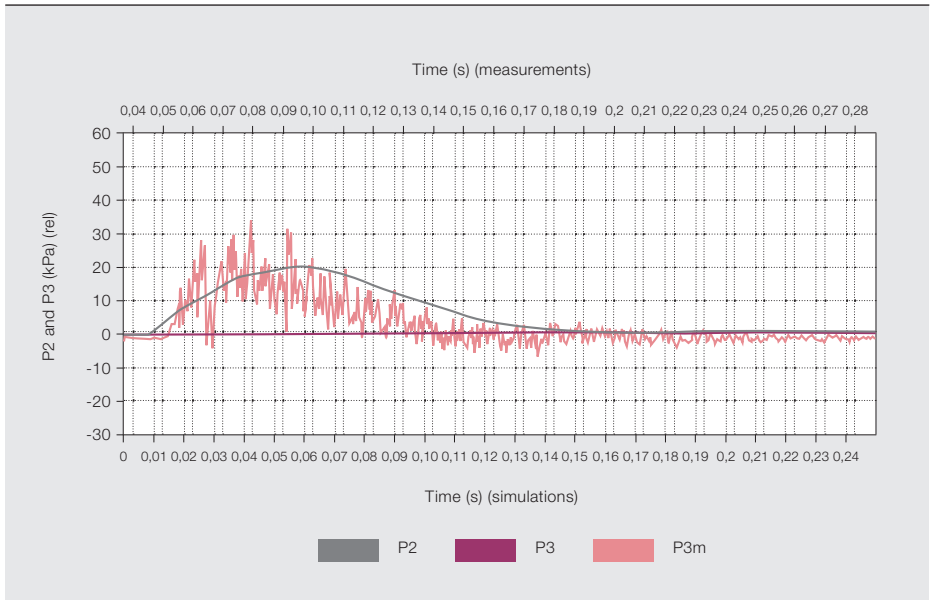
The first comparison relates to gas-insulated switchgear (GIS) where the insulating gas SF₆ could be replaced by air. The cross-section of the ABB switchgear ZX2, where the arc was ignited in the busbar compartment, is shown in → 2. The pressure relief device was a thin burst disc with an area of 0.049 m² opening into the channel on top at an over-pressure of 220 kPa. The fault current had a value of 39 kA and was applied for 1 s. The oscillograms show the time development of the calculated pressure in the arc compartment (black in oscillograms) and exhaust channel (gray in oscillograms), and the measured data

(purple for the former, pink for the latter) up to 250 ms after arc ignition.

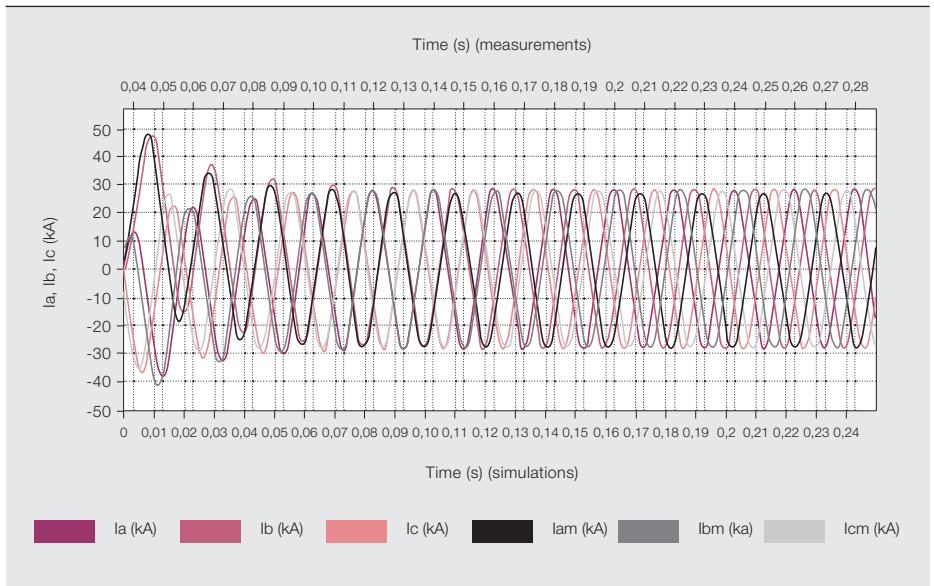
In → 3, measurement and calculation of pressure rise, peak and drop in the arc compartment filled with air are in good agreement. k_p is taken as 0.5 in accordance with published data, and arc voltage (phase-to-ground) of 300 V is taken from test. The calculation of pressure in the exhaust channel shows less satisfying correlation with the test results due to travel time effects of the exhausted gas, which cannot be implemented in the IAT. For the filling gas SF₆ → 4, the reproduction of the peak pressure is again good, but the drop of pressure after the opening of the relief disc is less satisfying. The calculation provides a longer residence time of the gas than observed in the test.

The exhaust of hot gas and subsequent pressure rise in a closed installation room were investigated in a special experiment.

7 Pressure in the container measured at another location than for → 6



8 Measured and applied phase currents showing the initial asymmetry



k_p is taken as 0.75 consistent with publications, and arc voltage is 400 V according to tests.

Many tests were recalculated. The inaccuracy in the peak pressure in the arc compartment is in the range of ± 20 percent, mainly determined by the uncertainty of response pressure of the relief device. The drop of pressure after relief is simulated with an error of a factor of two. This is of no concern for the assessment of pressure withstand of the switchgear, since it is the peak pressure that is decisive.

The peak pressure in exhaust channels can also be calculated. However, the inaccuracy might be up to ± 40 percent, which originates from the effects of pressure waves in elongated channels.

The exhaust of hot gas and subsequent pressure rise in a closed installation room were investigated in a special

The tool can calculate pressure rise in installation rooms with relief openings provided by, eg, windows or hatches.

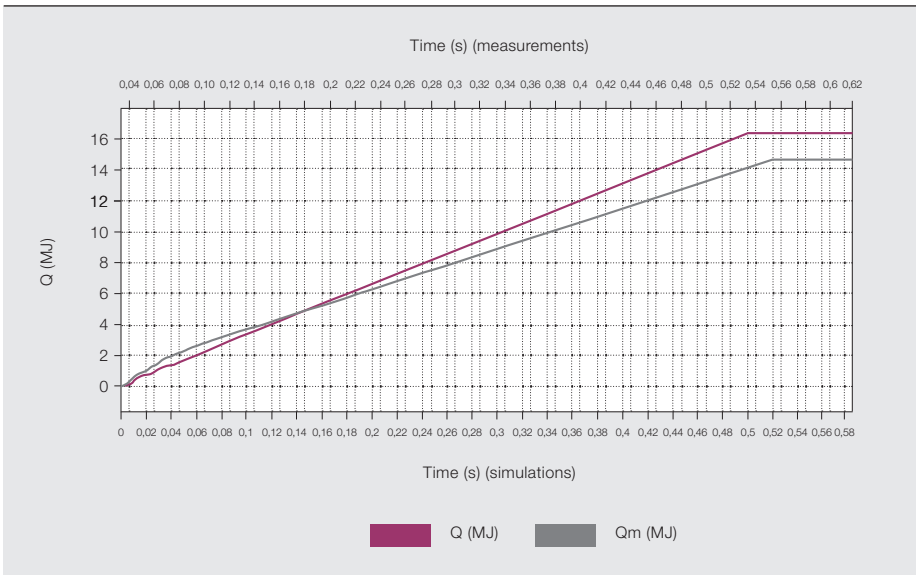
experiment [4]. The installation room was simulated by a gas-tight container of 8 m^3 . → 5 shows pressures determined in test and calculations. The drop of pressure in the arc compartment, after response of the relief device, deviates from the measurement, but the satur-

tion of the pressure rise in the container is simulated satisfactorily. This is due to the decrease of k_p implemented in the

IAT in dependence of the decreasing gas density in the enclosed switchgear compartment. If the arc energy heats up the total container volume uniformly in time, as for a freely burning

arc, the pressure would linearly rise to 345 kPa instead of the measured 154 and calculated 114 kPa.

9 Arc energy determined from the multiplication of phase-to-ground voltages and currents (purple from IAT; gray from measurement)



The calculation tool implements the density dependence of k_p according to the following formula applied for $\rho(t) < \rho_c$:

$$k_p(t) = k_p \cdot c_0 \cdot (\rho(t)/\rho_0)^{0.5}$$

c_0 is adapted to provide a continuous transition from the initial k_p . ρ_c is 1 percent of the normal gas density ρ_0 at 100 kPa for air and 20 percent for SF₆. Corresponding results were gained from the tests using SF₆ and air in a similar arrangement [4].

The tool can also calculate the pressure rise in installation rooms with relief openings provided by, eg, windows or hatches. → 6 shows a test result using the same 8 m³ container with a relief area of 0.3 m². The actual geometry of the installation room and the position of the relief opening and sensors cannot be considered in the IAT and will give deviations to reality. An example is the higher initial pressure in → 6 due to the direct stream of gas to the sensor. Another sensor positioned aside shows better agreement with the calculation → 7. Only computational fluid dynamics (CFD) may provide better results.

Estimated pressure

Within reasonable limits both peak pressures in the switchgear compartments and exhaust volumes match each other in test and simulation results. Inaccuracies are caused by the simplifications introduced in the tool (eg, ideal gas assumption and generic outflow function). The IAT can be used for simulation of the

pressure effects of fault arcs in switchgear. The uncertainty in the prediction of the peak pressure is in the range of ±20 percent concerning the arc compartment. A reliable arc voltage is required determined from tests on similar switchgear. The tool can also be used to estimate the pressure rise in an exhaust volume or installation room with or without relief openings considering proper safety margins. The internal arc simulation tool is a useful element to improve design efficiencies and increase safety, especially when it is impossible or impractical to carry out real-world testing.

The internal arc simulation tool is a useful element to improve design efficiencies and increase safety, especially when it is impossible or impractical to carry out real-world testing.

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- [2] Power installations exceeding 1 kV a.c. – Part 1: Common rules, IEC 61936-1, 2010.
- [3] WG A3.24, “Tools for the Simulation of Effects Due to Internal Arc in MV and HV Switchgear,” CIGRE Technical Brochure, to be issued 2013
- [4] E. Dullni *et al.*, “Pressure rise in a switchroom due to internal arc in a switchboard,” Proceedings of the 6th International Symposium on Short-Circuit Currents in Power Systems, pp. 4.5.1 – 4.5.7, 1994.
- [5] SOLVAY GmbH, “Schwefelhexafluorid,” company brochure.



From the basic to the complex

Optimizing an aging infrastructure in the modern grid

ROGER ESPERT, GARY FOUBERT – Hurricanes, tornadoes, blizzards, extreme temperatures – all occur on a regular basis. An obvious consequence of any natural disaster is the disruption of electrical networks. The monetary costs of these disruptions run into the billions of dollars annually.¹ In addition, vendors of medium-voltage overhead distribution networks are under increasing pressure to supply products with shortened delivery times so that their customers can deliver a reliable power flow. An aging infrastructure can make meeting these tasks challenging, to say the least. To meet the challenge, ABB is providing a range of solutions incorporating network applications and schemes through its vast portfolio of overhead installations. Providing a reliable and economic industry standard such as a basic fuse cutout with improved insulation, or providing the most advanced technology in switching and environmentally friendly applications in the form of an automatic recloser with IEC 61850 communication capabilities, are just two examples.



One of the most popular switching devices, the automatic recloser, has gained a significant role in the development of the smart grid.

To avoid the economic ramifications when outages occur, utilities must invest in maintaining their existing overhead lines and assets, both in terms of the quality of the cable conductors as well as the operating devices. This can become especially challenging for overhead networks suffering with assets that should be replaced or upgraded in order to avoid undesired outages and endure harsh climate conditions more resiliently.

Title picture

ABB is providing innovative solutions allowing utilities to optimize the grid for a better, safer, and more reliable energy supply.

Footnote

¹ According to an August 2013 report from the US White House, "Economic benefits of increasing electric grid resilience to weather outage," between 2003 and 2012 roughly 679 power outages, each affecting at least 50,000 customers, occurred due to weather events. Monetary costs of these outages account for up to between \$18 billion and \$33 billion annually.

But how can utilities overcome this situation while facing capital expenditure limitations, minimal operational costs and higher safety and reliability standards for power supply? Utilities can optimize the grid for a better, safer and more reliable energy supply to consumers by using either a proven ABB solution, an innovative technology developed by ABB or a combination of the two.

Advanced switching devices

Switching devices have been on the market for many years as a way for utilities to safely and quickly restore energy to their consumers. However the ability to automate those devices in order to take advantage of the existing technologies for telecommunication and monitoring to create a smarter and optimized

network are still a great task for many utility companies.

Different approaches and schemes can be deployed by the utility to merge proven technologies with innovative intelligent devices.

One of the most popular switching devices, the automatic recloser, has gained a significant role in the development of the smart grid. First introduced in the 1950s, this technology has gone through an astonishing development in the past five years, specifically in terms of the improvement of power electronics and the different communication capabilities. Today, it is normal to have meshed networks, GPRS/GSM communications from devices to a centralized SCADA (supervisory control and data acquisition)

1 An ABB GridShield® recloser with RER620 in a substation



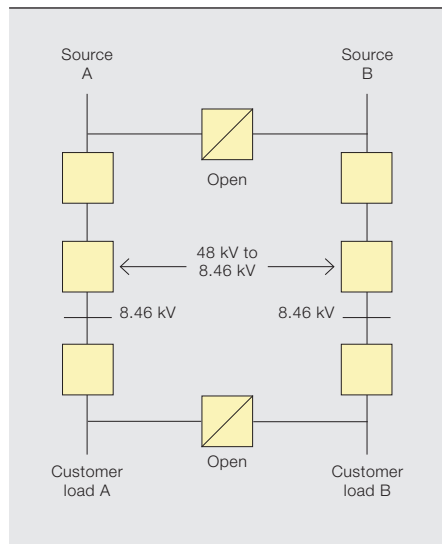
The ABB polymer concrete insulator cutout is unique in the industry, but growing in popularity among utilities.

system, and significantly faster situation awareness of a specific line on a period of time provided by the status of the automatic recloser.

Today's most advanced automatic recloser, the GridShield® recloser developed by ABB, has the proven technology of environmentally resilient solutions with components such as HCEP (hydrophobic cycloaliphatic epoxy), magnetic actuation and stainless steel, and incorporates the latest features in relay and communications → 1. The GridShield recloser is a resilient device and operates with the Relion® RER620, which has native IEC 61850, the global compatibility standard used from the substation to the point of delivery of the energy loads, while keeping the already well-known DNP 3 or IEC 104 as standard protocols. This innovative recloser takes advantage of the real-time monitoring status of a switching point that provides the SCADA operator, either by man-operated decision or automatic fault detection isolation restoration (FDIR). In the event of a fault, it can identify where the fault is and if it can be automatically cleared, and then restore power in a certain portion of the line.

Different approaches and schemes can be deployed by the utility to merge proven technologies with innovative intelligent devices. For example, even with substation automation using existing infrastructure, introducing an advanced relay at the substation circuit breaker, along with a communication system to interact with the downstream overhead

2 Redundant 8.46 kV lines power an industrial customer's facility



reclosers, the substation can maximize transfer performance and provide a reliable continuous power supply.

An example of this scheme has been proven in a US municipal utility where the results of the implemented transfer scheme test verify that it is possible to detect and transfer in less than four cycles → 2-4. The system fault detection, isolation, restoration and transfer scheme was based on the ABB Relion family of relays' native IEC 61850 capabilities with GOOSE, combined with R-MAG® distribution outdoor breakers and GridShield reclosers.

Fuse cutouts

For years, electric utilities have relied on cutouts in the power distribution grid in overhead distribution systems to provide overcurrent protection.

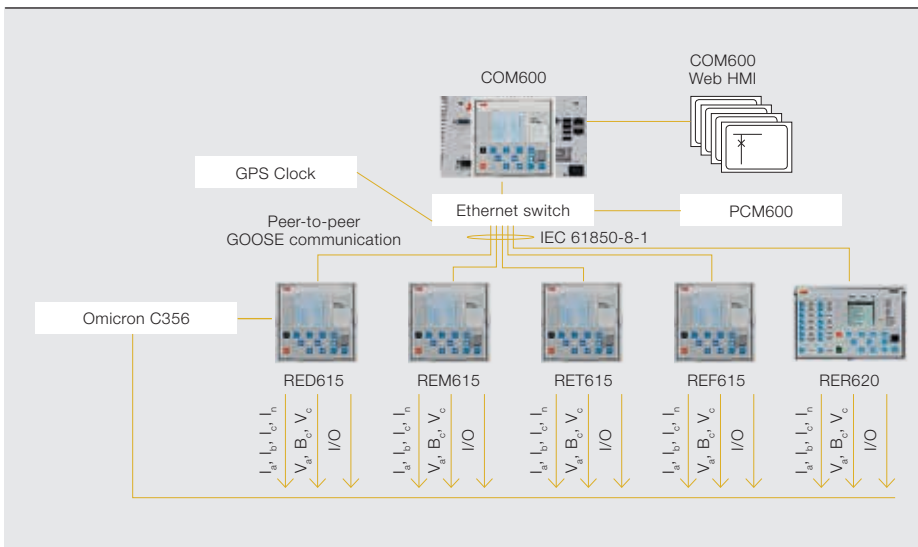
By the early 1970s distribution cutout insulators made from porcelain were a key component in most utilities' protection, security and operation of the distribution system. In the 1980s, however, PPL Electric Utilities, a US-based utility serving over 1.36 million electricity consumers in the state of Pennsylvania, noticed the porcelain cutouts it had used for many years were becoming increasingly damaged or affected by the cold-weather climate of the Northeast.²

The brittle nature of the porcelain insulator also made it susceptible to breakage from handling in transit and during installation. During extreme cold periods moisture ingress would freeze, expand

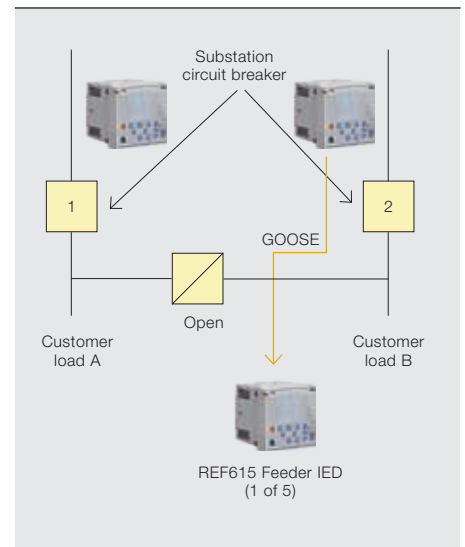
Footnote

2 See also: M. Berner and M. I. Abdelrahim, "Successfully Breaking the Mold with Polymer Concrete Cutouts," *Utility Products*, May 2011.

3 ABB's distribution automation verification lab configuration replicates a utility's field configuration.



4 An application example of feeder protection and control IEDs



5 ABB's polymer concrete insulator cutout



and crack the insulator, which ultimately would lead to mechanical failure.

Polymer concrete search

Concerned about the degrading quality of its porcelain cutouts, PPL approached ABB in 1988 about creating a polymer cutout.

In 1990, PPL undertook a program to install all new cutouts using the ABB polymer concrete-designed cutout product. The ABB polymer concrete cutout came with all the common features but also provided additional benefits, including cold-weather reliability, durability, and excellent electrical properties and dielectric strengths.

To verify that the polymer concrete cutouts had performed without an insulator failure, PPL tested a small sample of the cutouts installed on its system. The company selected 30 units that were in ser-

6 ABB Smart Grid Center of Excellence in Raleigh, North Carolina



vice for 12 to 14 years on its distribution system. The sample units were tested by ABB, an independent testing lab and another utility's testing lab. The results from all tests verified that the units performed without failure while exposed to the typical harsh weather conditions for the northeastern United States.

PPL reports that, with more than 250,000 units installed over the last 20 years, there has not been a single known cracked polymer concrete cutout in its network.

The ABB polymer concrete insulator cutout is unique in the industry, but growing in popularity among utilities, as it provides excellent electrical properties and dielectric strengths, as well as superior mechanical toughness → 5. ABB's cutout and switch designs are available with a polymer concrete insulator.

What's next?

Without question, the use of field-proven devices, even as traditional as a cutout, will be an integral part of solutions for years to come. And yet the merging of simple solutions with complex intelligent devices providing communication and flexibility is what allows ABB to offer sustainable solutions for different global requirements → 6.

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Power house

A strong and light enclosure for substations

ALEXANDRA L. GOODSON, BRIAN C. JOHNSON, DANIEL TURK – ABB's latest compact secondary substation (CSS) provides utilities with smart and efficient equipment that provides real-time data, reliability and a performance that ensures the network meets customer needs. Extending the life of such equipment means that utilities have lower maintenance costs and fewer replacement or warranty concerns. The provision of an appropriate enclosure for the CSS is a very important strategy for extending equipment service life. Traditional steel, concrete or brick structures have many drawbacks concerning space, speed and flexibility of installation, and environmental robustness. ABB's state-of-the-art glass reinforced polyester (GRP) enclosure obviates all these concerns and provides the perfect housing for a CSS and many other electrical applications.

It is robust enough to protect the equipment inside from the extremes of heat and cold, while being lightweight enough to be easily transported to remote locations.

The CSS market was created when distribution utilities transitioned from overhead power lines to underground cables. With cables underground, the traditional, large step-down substation with its overhead lines became impractical. Customers now required a compact piece of equipment that could be installed quickly with a minimum of site work but that provided the same functionality as an overhead line substation.

Concrete

Driven by aesthetics and safety concerns regarding overhead lines, Europe was one of the first regions to embrace the practice of undergrounding cables and installing CSSs. CSSs can be built on-site with either brick or concrete. Concrete is weather-resistant, but very heavy, difficult to work with and on-site construction labor costs can be significant. However, if the unit is preassembled before shipment to site, the transportation and rigging costs can be excessive as a concrete CSS weighs, on average, 24 t. If the CSS is heavier than 24 t, separate shipments to site may be

needed due to transportation limits, further complicating matters. Concrete CSS factories are located in many regions and close to customer sites in an effort to lower transportation costs.

ABB recognized that customers needed a new CSS enclosure solution – one that combined the benefits of steel and concrete.

While this situation may have been acceptable years ago, it is now challenged by population growth and city expansions that force CSS installations further away from the CSS factory.

Steel

As underground cabling and urbanization continued apace, new, rural locations began to create challenges for heavy concrete CSSs. A lighter and cheaper solution was needed for this

evolving CSS market. A steel enclosure was found to fit the bill. With the comparatively lighter weight of a steel CSS, transportation to rural locations was no longer as expensive and heavy on-site installation work was not required. Steel provided the same functionality as concrete but the CSS had an average weight of just 12 t. This allowed CSS units to be transported and rigged without significantly impacting budgets.

However, while lighter than concrete, steel does not have the same strength and is more sensitive to ambient weather conditions. High levels of sunshine may increase the steel temperature to such an extent that a derated transformer has to be used, thus lowering the overall efficiency of the CSS.

ABB recognized that customers needed a new CSS enclosure solution – one that combined the benefits of steel and concrete. Ideally, it would be robust enough to protect the equipment inside from the extremes of heat and cold, while being lightweight enough to be easily transported, even to remote locations. To fulfill this need, ABB developed a modular platform that encompasses the strength and durability of concrete with the lightweight characteristics of steel. The platform is suitable not only for housing

Title picture

The robustness and flexibility of ABB's UniPack-G make it the ideal enclosure for the complete spectrum of ABB's smart grid product portfolio.

Concrete structures are susceptible to damage during transport or from manhandling.

1 Concrete structures are susceptible to damage during transport or from manhandling.



CSSs, but also for housing a wide range of other electrical equipment. In addition, it is appropriate for cold, moderate and warm climates and for locations ranging from sea-spray-soaked coastlines to remote, heat-seared sandy deserts. This new product range is called UniPack-G, where G stands for glass-reinforced polyester (GRP). GRP is a material used in many everyday applications, such as wind turbine blades, boats, civil construction, cable pillars and garden furniture, to name but a few.

UniPack-G

GRP is unaffected by temperature change and can withstand attack by salt and humidity. As a UniPack-G CSS enclosure weighs far less than its equivalent in concrete or steel, transportation costs are reasonable and installation in remote or difficult locations is far easier. Although lighter, GRP has greater durability than both concrete and steel. Since a CSS can be installed in publicly accessible locations, the UniPack-G's inherent ability to withstand vandalism is important. UniPack-G's durability also ensures there will be no damage from transportation or shifting, as can occur with concrete → 1.

The UniPack-G design has been tested to the highest safety standards in the GB and IEC ranges for CSS applications. In addition, the standard UniPack-G design has passed the internal arc classification (IAC) test, which ensures it has the highest level of safety for the public and for operating personnel.

2 Steel structures are prone to deterioration in many environments.



Location

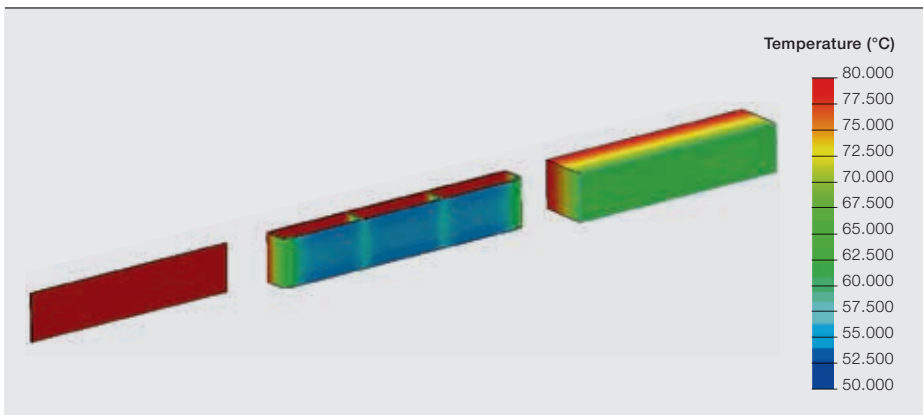
Ever more rural and environmentally harsh locations are being supplied with electricity. Because the UniPack-G has the same robustness as a concrete CSS – with one-third of the weight – and on-site installation and material handling effort is minimal, it is ideally suited to this type of location. UniPack-G is easier to transport over longer distances and it requires less lifting effort. This reduces the utility's reliance on local suppliers and allows it to depend on ABB, who can exploit and pass on the advantages that come with being a global supplier.

Rural and environmentally harsh locations usually require low-maintenance equipment because of remoteness and difficulty of access. In addition, the smarter networks now being installed around the globe can be controlled and monitored remotely, so CSSs are visited less often and this reinforces the requirement that equipment be as maintenance-free as possible. The UniPack-G has an exterior that can withstand severe conditions better than a typical CSS enclosure, it is corrosion-resistant and never has to be repainted → 2. In addition, UniPack-G's GRP enclosure material does not dampen radio waves, so communication antennae can be installed inside to reduce the risk of vandalism. These features all reduce the maintenance effort and cost for the utility.

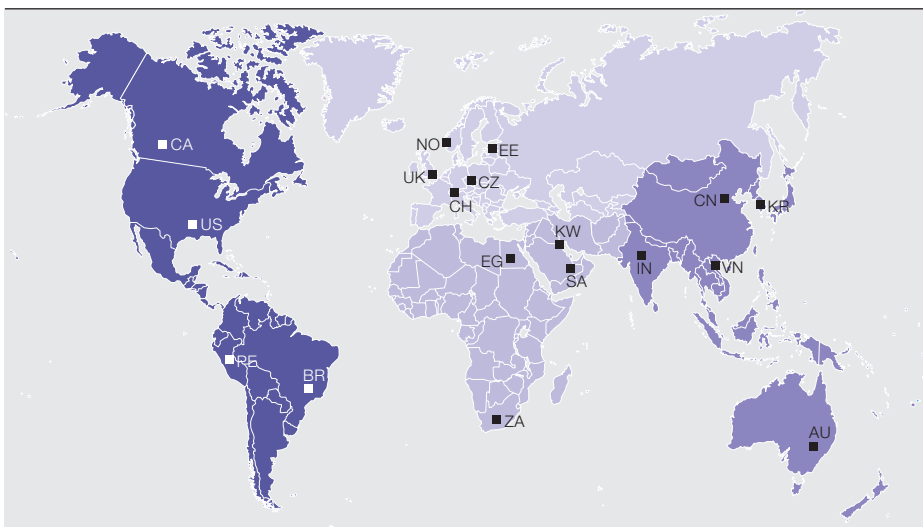
Insulation

Electrical equipment and automation electronics are often sensitive to humid-

3 The UniPack-G (middle image) impedes heat ingress far better than steel (left) or concrete (right).



4 ABB has factories and personnel to support all GRP projects. The map highlights ABB's global CSS footprint. (The map colors indicate ABB marketing regions.)



ity and temperature. For this reason, steel CSSs require additional insulation, which can be difficult to install. Concrete CSSs require less insulation in warm environments but need to be heated in cold locations or when in idle mode.

UniPack-G's double-layer design ensures that ambient temperatures do not affect the equipment inside → 3. The figure shows the high level of insulation provided by ABB's UniPack-G. The first image shows the interior wall of a typical steel enclosure in intense sunshine – the interior will be difficult to keep cool and this will affect the performance of the equipment inside. The second image highlights the UniPack's double layer insulating design: The red of the exterior wall demonstrates an environment with high solar irradiation, while the blue of the interior wall reflects the cool internal temperature. The ability to maintain the internal temperature, regardless of external conditions, is inherent in the double-layer feature of the UniPack-G, which is

included in all standard solutions. The third image represents a concrete enclosure wall. While the heavy wall is thicker, the light green of the interior wall shows it is not as cool as the UniPack-G.

The temperature consistency inside the UniPack-G allows equipment to run at its highest efficiency and without the need to derate. This increases the utility's return on investment and ensures a high equipment utilization rate.

UniPack-G's flexibility makes it the ideal enclosure for the complete spectrum of ABB's smart grid product portfolio – including monitoring, control, measurement and protection products. Its modular design offers flexibility and allows a wide range of other electrical equipment (eg, energy storage modules, E-houses and solar inverter stations) to be accommodated, while still abiding by transportation, installation and durability requirements.

UniPack-G's GRP enclosure material does not dampen radio waves, so communication antennae can be installed inside.

GRP's features, along with emerging applications, provide new opportunities for grid solutions and utilities can now work with one supplier for all their GRP needs. GRP is a material that supports these initiatives, while ABB provides a global footprint and support → 4. Customers demand a smart, optimized and safe CSS solution and ABB's UniPack-G portfolio exceeds the customers' requirements by combining concrete's benefits, steel's lightweight features and smart grid compatibility.

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Compact and eco-efficient

Meeting the need for a more environmentally friendly ring main unit with the innovative SafeRing Air

TOM-RUNE BJORTUFT – As a leader and pioneer in power technologies, ABB is always looking for ways to design and manufacture products that improve grid reliability with the lowest environmental impact. Concerns related to the greenhouse effect of SF₆ are driving the development of a new generation of power distribution products based on alternative insulating gases. From an environmental perspective, dry air is one of the most desirable alternatives seen today. In order to meet the increasing demand for

solutions with lower environmental impact, ABB developed SafeRing Air, a compact ring main unit within the SafeRing/SafePlus portfolio. Using dry air as the insulation medium and with vacuum technology for current interruption, SafeRing Air is available for up to 12 kV in circuit breaker and load-break switch configurations. This new offering is intended for a selected market segment in addition to the traditional RMUs, which cover the complete portfolio in secondary distribution gas-insulated switchgear.



The recent introduction of SafeRing Air → 1 enables ABB to provide another ring main unit (RMU) alternative to its customer base. The traditional SF₆ solution already meets the requirements of customers who are looking for closed SF₆ handling and a very low leakage rate. The innovative SafeRing Air is the perfect solution for customers who seek to lower the carbon footprint even further. For the 12 kV RMU market, SafeRing Air is a solution that has the same physical dimensions, operation sequence, technical performance and quality as the traditional SafeRing with SF₆. It also comes with a new feature – the ability to upgrade a load-break switch panel to a circuit breaker panel on-site. This is an important differentiator that is not seen elsewhere in today's marketplace and is made possible by the use of vacuum technology for current interruption on both fault currents as well as load currents. The physical weight is reduced by 6 to 7 percent on high-volume configurations (typical CCV) and up to 19 to 20 percent on less common configurations (typical VVVV), compared with the tradi-

Title picture

ABB is creating technologies with greatly improved environmental measures.

tional technology. This also has additional advantages for transport or installation, for example.

Unique gas

SF₆ is used as an electrical insulator, as a thermal conductor and to interrupt current flow. The current technology obtains the necessary compactness and

Challenges

The main technical challenge in developing an RMU with an alternative environmentally friendly insulation gas has been to maintain the same physical size. Maintaining the outer physical dimensions of the unit is vital since this places strict conditions on the dielectric and thermal performance.¹

Maintaining the outer physical dimensions of the unit is vital since this places strict conditions on the dielectric and thermal performance.

technical performance within gas-insulated switchgear (GIS). No alternative gas has been identified that exhibits the excellent properties of SF₆. During the last decade, several gases have been explored, but many tend to suffer from high liquefaction temperature and/or reduced dielectric strength. SF₆ is well known for its excellent properties within applications and products for the electrical distribution industry, but it is also classified as a greenhouse gas.

Dielectric design targets the distribution of electrical fields within the unit, aiming to reduce the field strength of weak points to compensate for the reduced dielectric strength of alter-

native insulating gases. Key parameters for optimization include choice of insulating materials, geometrical shape of conducting surfaces and definition of conductor/insulator interfaces. Advanced simulation tools are used for this pur-

Footnote

¹ These challenges have recently been discussed in CIRE paper 0463, "Dielectric and thermal challenges for next generation ring main units," 2013.

SafeRing Air has been designed using the same logic that was used for traditional RMUs with SF₆, leading to a well-known operating sequence.

pose, and results are validated by dielectric tests in full-scale units.

Thermal design is critical due to the lower thermal properties of alternative insulating gases, compared with SF₆, and has two main objectives. The first is to reduce ohmic losses to a minimum by utilizing a sophisticated design of select materials, surface treatment, contact forces, etc. Reducing ohmic losses increases energy efficiency.

The second objective is to distribute the heat-generated losses through a combination of conduction, convection and radiation. Computational fluid dynamics (CFD) analysis is needed to understand and optimize the temperature distributions inside the switchgear. Such simulation results are validated by temperature rise tests in full-scale units.

Besides these key challenges, other factors have been considered in developing the SafeRing Air RMU. ABB is committed to providing customers with the safest products and Safering Air is no different. Technical parameters and tests set by the IEC and other relevant standards were done to ensure safety when operating the RMU.

Another aspect is keeping the simple mimic, easy and logic operation of the RMU. To take this fully into account, Safe Ring Air has been designed using the same logic that was used for traditional RMUs with SF₆, leading to a well-known operating sequence. And of course environmental measures such as life-cycle assessment (LCA), environmental product declaration (EPD), and environmental product information (EPI) have been met.

Environmental measures

Clearly, meeting environmental measures are of great importance when introducing an environmentally friendly offering to the marketplace. ABB undertook a detailed LCA analysis of the SafeRing Air RMU. The main intention of such analysis is to provide a base for customer information. This base is established by using the experience from the LCA analysis to set product category rules (PCRs) in order to establish a standard for the MV switchgear business. The overall goal was to provide relevant and comparable product information to meet various customer and market needs.

Commercial perspectives

A recent figure released by the World Energy Outlook 2013² states that the energy sector represents two-thirds of global greenhouse-gas emissions, and hence is an important sector for improvement for reaching the globally agreed 2 °C target. The energy industry is therefore under pressure in terms of global energy/climate policies. The European Union also has strict regulations for the use of f-gases, where SF₆ is one of the most important greenhouse gases (GHGs). This regulation is linked to the EU climate policy with the overall objective of cutting GHG emissions by 80 to 95 percent by 2050. This, together with new policies in, eg, China, opens up a demand for proven and readily available products with lower environmental impact. The shift of technology with improved environmental measures will require heavy investments and years of development to enhance and complete today's global product portfolio. With this first product launch for secondary GIS, ABB shows that this global challenge is on top of its agenda.

Customer feedback prior to the launch of SafeRing Air confirms ABB's strategy and shows an increasing demand for such solutions in the low-end portfolio (12 kV).

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Footnote

² WEO 2013 executive summary, International Energy Agency, 2013.



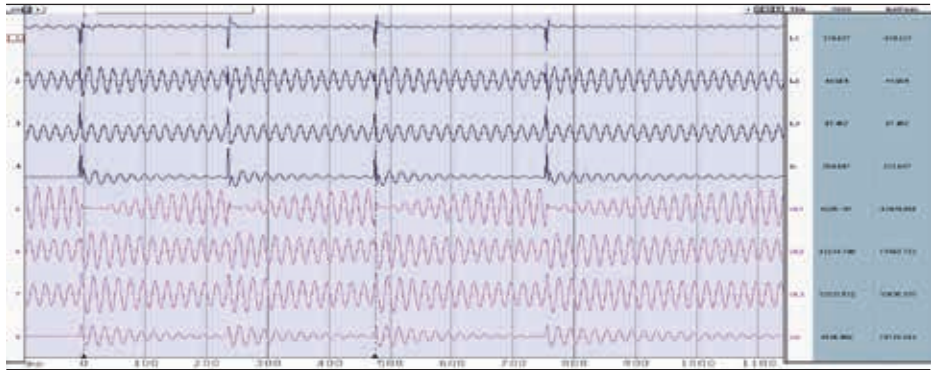
Earth science

A new digital earth-fault detection method improves reliability

ARI WAHLROOS, JANNE ALTONEN – Temporary earth faults cause the majority of outages in power networks. Compensation coils connected to the neutral point of the network can significantly reduce these outages but they do nothing to help detect the faults themselves. Indeed, the benefit of reduced fault currents that coils bring, inherently complicates fault-finding. In addition, faults may be intermittent and manifested as high transient currents and voltages. Earth-fault detection and directional determination in compensated distribution systems are the

two most challenging and important tasks taken on by protection relays. After years of intensive research, development work and field testing, ABB has now introduced a reliable digital solution that accomplishes these tasks. This obviates the need for an additional and separate analog transient relay and its associated costs. The new functionality is integrated into the very popular Relion® 615 series protection and control relays for distribution networks and, in particular, in the REF615 for feeder protection and control.

1 Typical voltage and current waveforms during a restriking earth fault



Statistics show that the majority of faults in unearthed and compensated medium-voltage networks are earth faults. According to studies made in the Nordic countries, about 50 to 80 percent of all faults are in this category [1]. These faults are very often characterized by current and voltage transients.

It is common for national regulatory models to require consumers to be compensated for failures in power provision (or for poor power quality). Also, the consequences of short outages have become more significant as society has become increasingly dependent on high quality and reliability of supply. It is, therefore, clearly in the interests of utilities and distribution system operators (DSOs) to minimize supply interruption caused by earth faults.

In recent years, resonant grounding has become a growing practice worldwide in neutral point treatment of medium-voltage networks. Such grounding reduces the capacitive earth-fault currents pro-

duced by the network to close to zero and alleviates the conditions for self-extinguishment of earth faults without the need to trip breakers and cause customer outages. However, such low fault currents, which do not even trip breakers, make it difficult to detect the fault and its direction. In addition, faults can be intermittent, ie, they can self-extinguish very rapidly but then reignite due to degradation of the insulation dielectric at the fault location. Such intermittent faults create highly nonsinusoidal and irregular voltage and current waveforms, which conventional relay algorithms are not designed to handle → 1. This can cause relays that trigger on persistent fault signals to either fail to operate or trip non-selectively. This can lead to the disconnection of an entire primary substation.

Therefore, up until now, utilities and DSOs have always required, and preferred, earth-fault protection that is based not on steady-state measurement

Analog measuring relays were considered to be the only reliable way to measure transients and no digital alternative has been available, until now.

signals, but on initial fault transients. Analog measuring relays are considered to be the only reliable way to measure transients so these have been enshrined in utilities' internal guidelines – regardless of the additional work, cost and space requirements that these devices bring with them.

No digital alternative has been available, until now.

The reliable digital solution

After years of intensive research, development and field testing, ABB has succeeded in producing a reliable digital alternative to the analog approach. This takes the detection of transient and restriking earth faults to a new and more sophisticated level. The patented algorithm utilizes the latest developments in protection algorithm design, including multifrequency neutral admittance measurement and sophisticated filtering techniques. The principle functional diagram of the algorithm is illustrated in → 2.

The first fundamental novelty of the algorithm is the multifrequency neutral admittance measurement. This utilization of harmonics makes the protection algorithm very robust and reliable even if the measured signals are distorted or include high frequency components, as would

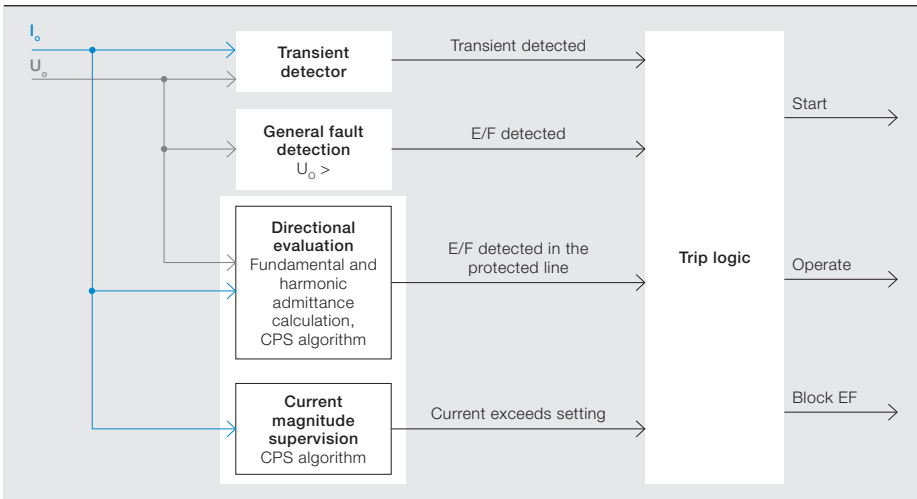
be the case in a restriking earth fault.

A second novelty of the algorithm is its directional element, where the discrete directional admittance phasors are replaced by the accumulated values of the same quantities during the fault. This filtering technique is called cumulative phasor summing (CPS). The directional phasor calculated by the CPS technique gives a very distinct and stable indication of the fault direction as the accumulated fault phasor points in the direction of the highest energy flow, ie, in the fault direction.

Title picture

ABB's digital method of earth-fault detection and directional determination makes life a lot easier for power network operators, like the owners of this distribution station in California.

2 Principle of novel restriking earth fault (E/F) protection



4 Energizing a damaged cable initiates a restriking earth fault



Fewer and shorter outages and faster fault localization

The algorithm provides a highly robust and selective fault identification and direction determination during restriking and transient earth faults. It is sensitive enough to detect the smallest current spikes likely to occur during a restriking earth fault in today's extensive cable networks. Early detection of an intermittent fault prevents it from evolving into a more serious malfunction – for example, a double earth fault with high fault currents.

Current regulatory models motivate utilities and DSOs to minimize the number and duration of supply interruptions caused by intermittent earth faults. This new digital approach to earth fault investigation facilitates this in a simple and cost-effective way.

Reliability proven in field tests

In recent years, ABB has undertaken intensive field testing in cooperation with selected power utilities in order to test and develop new earth-fault protection functions. The novel algorithm discussed here was developed in close cooperation with the Vattenfall utility in Sweden, where it has been extensively tested with actual disturbance recordings representing a wide variety of network and fault conditions → 3.

Collaboration is the key to success

Vattenfall is a good example of a close collaboration with the customer during product development leading to well received products that fulfill the customer's requirements. Collaboration agreements will continue to be an important factor in product development. Future products will assist customers to further increase power availability and thus improve the profitability of their business.

3 Field testing

The latest field test took place in a 10 kV HV/MV substation owned by Vattenfall, one of Europe's leading energy companies, in Sweden → 4. The test infrastructure was a large rural cable network with central and distributed compensation. The operation of the new Relion 615 digital earth-fault detection functionality was demonstrated in 51 individual test cases in which the fault type (permanent, restriking), location (of four) and the compensation degree (undercompensated, fully compensated and overcompensated) were varied. The algorithm worked in all cases. The results showed that with the novel algorithm, high-security and dependability requirements of the protection scheme could be met.

"The tests went really well. Moreover, tests performed in a real-life setting are a good opportunity for us, as a customer, to show what our needs are. I think both parties learn a lot from this kind of test," said Ulrika Uggla, protection engineer with Vattenfall in Trollhättan.

For Vattenfall, it is important that the earth-fault relay is able to detect transients in earth faults. One reason is that transients can indicate where in the grid the fault is located. Another reason is that if the relay is not triggered by recurrent transients, a greater part of the system may be disconnected than would otherwise be necessary. In the new REF615 series, the protection relay can be triggered selectively. It disconnects the correct cable and prevents fault-free parts of the system from being disconnected. This can mean, in one concrete example given by Vattenfall, that only 1,000 homes are affected by a temporary power outage rather than 8,000 homes.

The work described here has led to a better understanding of new challenges and problems faced by modern distribution network providers. This provides impetus to further develop intelligent electronic devices and functionalities for medium-voltage networks. Already, based on the experienced gained from this cooperation, a prototype of an even more capable earth-fault detection algorithm is being developed.

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Janne Altonen

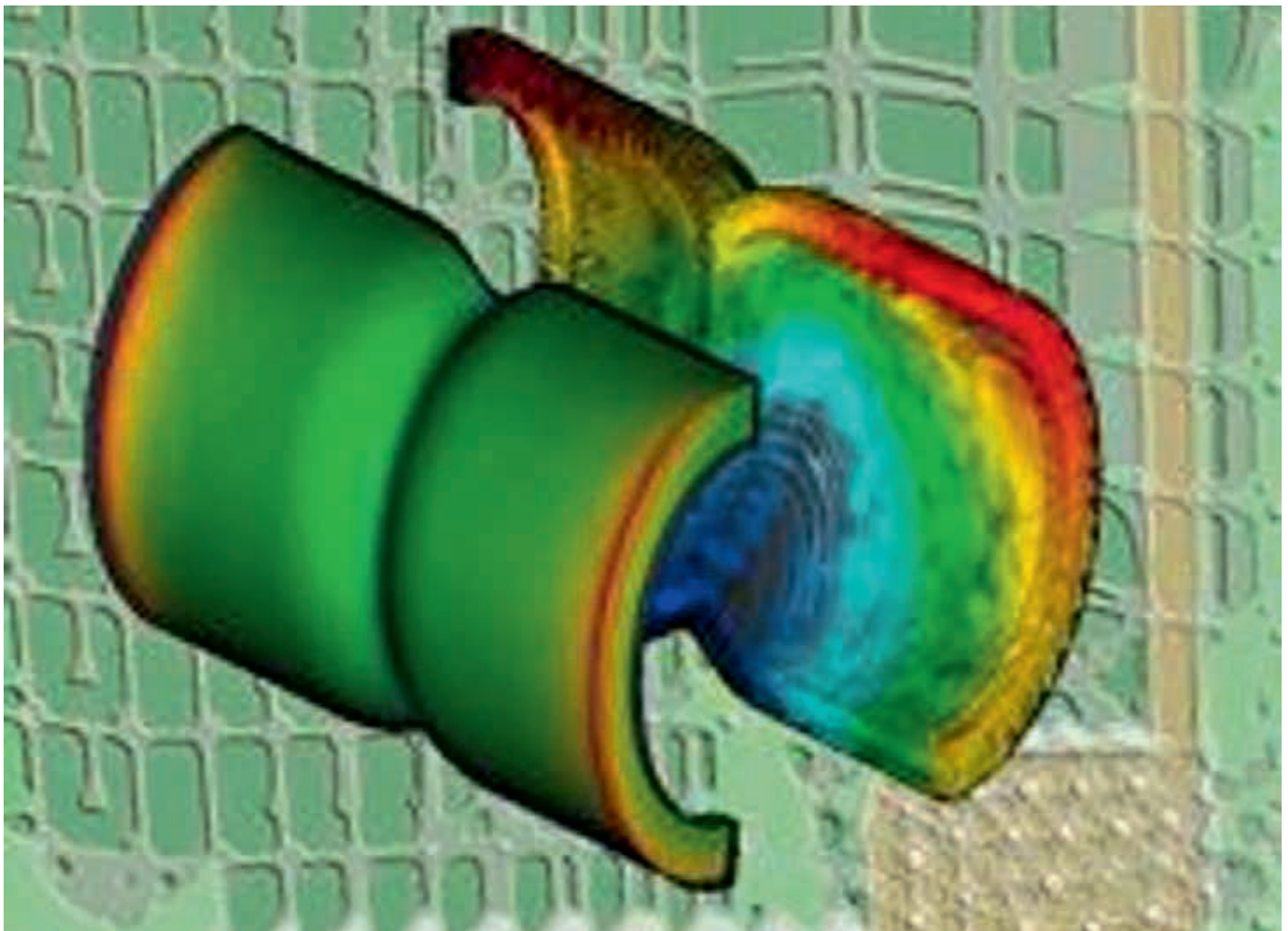
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Molding the future

Polymers processing enhanced by advanced computer simulations

ROBERT SEKULA, KRZYSZTOF KASZA, LUKASZ MATYSIAK, LUKASZ MALINOWSKI, DARIUSZ BEDNAROWSKI, MICHAL MLOT, GERHARD SALGE – Due to their excellent electrical, thermal and mechanical properties, polymeric materials are the principal insulating materials used in many ABB power products. Because of the shape complexity and wide range of parameters used in manufacturing technologies, there can be product quality challenges. For example, air voids, incomplete filling, premature gelation, incorrect curing propagation, local overheating, cracks and deformations may appear in the insulation. However, through advanced computer (numerical) simulation tools, ABB maintains the highest quality control of its products, and minimizes the development time of new products. These simulation tools allow engineers to explore thousands of design alternatives within very short time periods, leading to improvements in performance and design quality, and reducing the time required to bring a product to market.

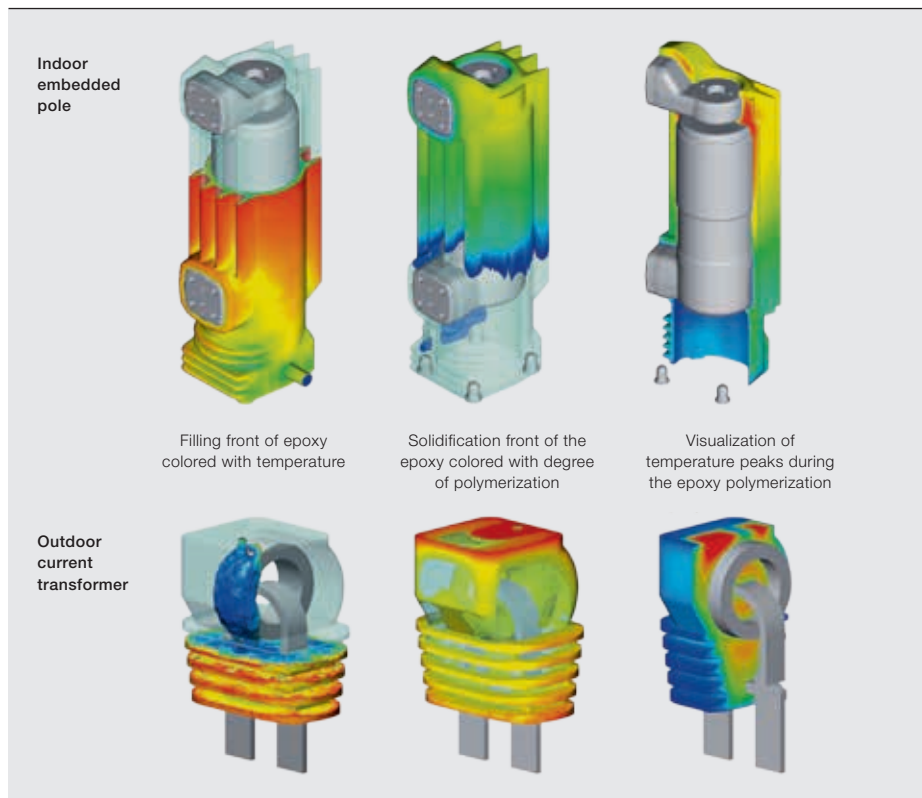


ABB uses advanced computer simulations in all of its polymers processing technologies, including reactive molding, injection molding, and silicone molding.

Epoxy casting

Epoxy resins are the principal insulating material used in manufacturing ABB's medium- and high-voltage products. The complex manufacturing process, referred to as reactive molding, includes casting, gelling (solidification) and cooling. By using a multiphysics approach that brings together advanced computer simulations of fluid flow, heat transfer, mechanical deformation and stresses, more accurate results are achieved and engineers are better able to follow and control the manufacturing process.

They can observe the mold filling with epoxy resin, the material transition from liquid to solid state, temperature distribution with temperature peaks caused by exothermic chemical reaction, shape deformation during the cooling and related buildup of stresses [1, 2] → 1. Detailed

analysis of the obtained results helps in selecting the best process parameters. Maintaining the right processing temperatures and minimizing the residual stresses are the key factors that determine the final product quality and reliability.

ABB has also developed a Web-based epoxy casting simulation tool that offers fully automated calculations [3]. The cal-

To maximize the composite potential in the development of its thermoplastic components ABB uses advanced simulation.

culations can be performed directly by design or process engineers with no numerical modeling background. The mesh generation, simulation setup, calculations and other steps are done automatically based on input variables like model geometry, selected materials and process parameters. The tool generates a report with a summary of the results that can be used to analyze the process regarding its quality and efficiency.

Thermoplastics injection molding

Thermoplastic polymers, used predominantly in ABB low-voltage products, are distinguished from epoxies and other thermosets by their ability to be melted and molded when heated above certain temperatures, returning to a solid state upon cooling. Injection molding is the most common processing method for thermoplastics. Hot, melted polymer is

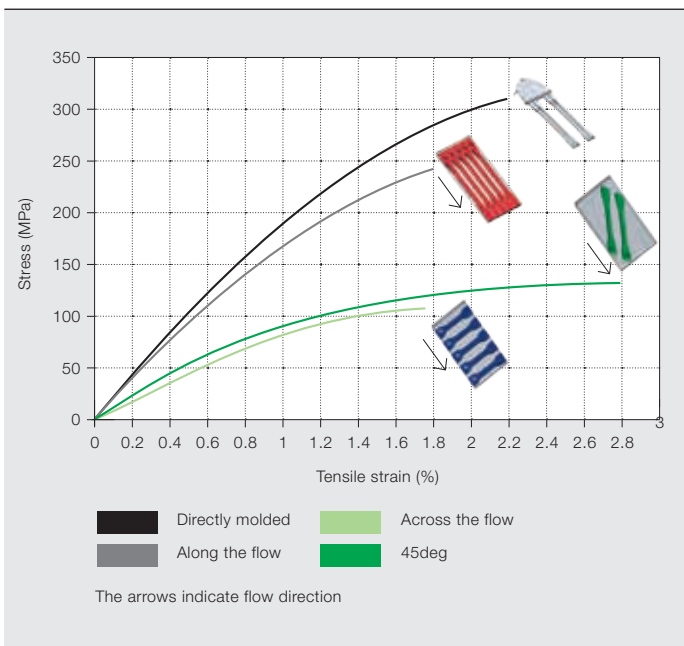
injected at high speed (up to hundreds of cm³/s) at high pressure (up to 2,000 bars) into a cold mold cavity; while the polymer is cooling, the pressure is maintained by the injection unit in order to compensate

for shrinkage. When the polymer temperature is 20 to 30 °C below the solidification temperature enough mechanical strength has been gained so that the part can be ejected. Production cycle time depends on wall thickness (starting from 0.5 to 6 mm) and usually takes from a few to around 100s. Part and mold design is very challenging because of the complex phenomena occurring during thermoplastics processing – eg, shearing, viscous heating, crystallization, ori-

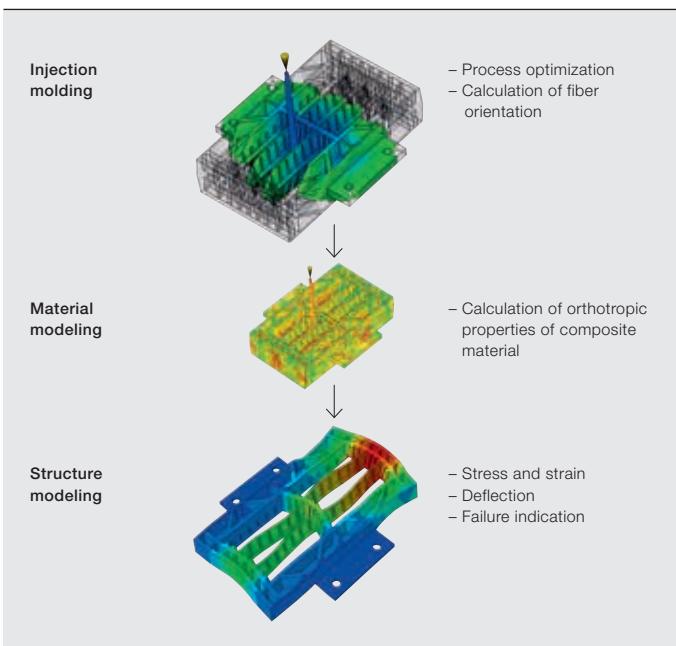
Title picture

Optimization of a sample component achieved with injection molding simulation.

2 Comparison of tensile test results for polyarylamide 50 percent glass fibers in the case of different orientation of short fibers



3 Simulation approach for short fiber reinforced thermoplastics processed by injection molding



Advanced computer simulations are conducted in order to optimize each part and mold design before mold fabrication.

entation, cooling and undesired deformation (warpage).

Advanced computer simulations are conducted in order to optimize each part and mold design before mold fabrication.

The computer simulation tool allows analysis of all the processing stages: injection, packing and cooling (ejection time and its impact on heat distribution in the mold is even taken into account). The simulation model considers all the essential components of the injection mold, such as part cavity, cold or hot runner system, part or mold inserts, cooling circuits, and mold venting if necessary. Computer simulations help evaluate the quality of the injection stage in terms of filling profile, flow stagnation, premature polymer freezing or location of weld lines and air traps. During the packing and cooling stages the efficiency of shrinkage compensation is evaluated so that the correct selection of a cold gate cross-section can be made. The shape of the final part is also modeled by taking into account warpage caused by the polymer shrinkage, uneven cooling and material orientation.

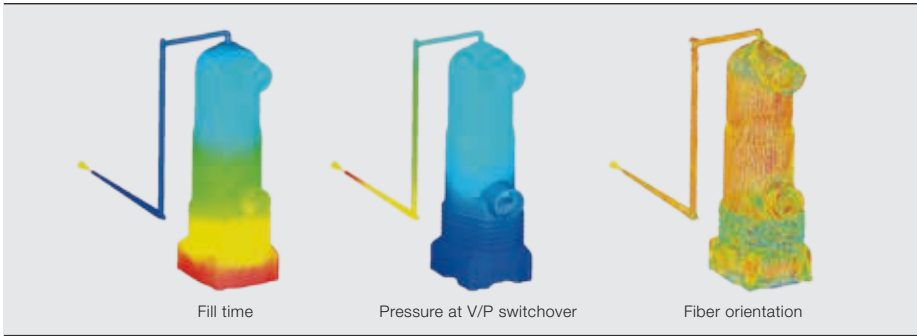
The software used for injection molding simulation includes a database with over 6,000 predefined thermoplastic materials, which can be used for material specification – eg, pressure-volume-temperature (PvT), viscosity as a function of temperature and shear rate, and thermal and me-

chanical properties. The software also handles processes like gas-assisted injection, injection compression, co-injection and fiber-reinforced materials.

Thermoplastic composites reinforced with short glass fibers are also often used as insulating material because of their excellent mechanical and thermal properties. Introducing these materials into a product is challenging because the short fibers in a polymer matrix are aligned in flow direction during the injection-molding process resulting in anisotropic material properties. The highest stiffness and strength is measured in the direction of material flow during molding, while the transverse performance could be only 35 percent of material datasheet values (based on measurements for polyarylamide reinforced with 50 percent glass fibers) → 2.

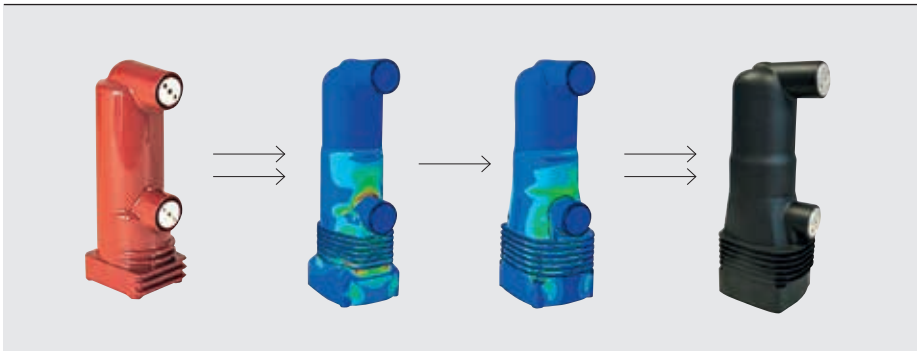
To maximize the composite potential in the development of its thermoplastic components ABB uses advanced simulation → 3. The first step of the simulation process is to gather information on fiber distribution. Material properties of polymer matrixes and fibers are defined separately in the material modeling software, which calculates the resulting mechanical properties of the composite. These values are then used by a structural simulation package to calculate product response under applied mechanical load. Estimating the critical load that can be carried out by the composite material

4 Simulation results of injection molding process of thermoplastic embedded pole



The dielectric performance of the design is checked with the simulations of the electric field distribution.

5 Mechanical optimization of thermoplastic embedded pole structure



becomes feasible with stress- and strain-based failure indicators [4, 5].

From epoxy to thermoplastics

Thermoplastic materials have been widely used in low voltage products applications. With the increasing capabilities of engineering thermoplastics, they are also being considered as a replacement for thermoset epoxy insulation for higher voltage level products. The mechanical properties of engineering thermoplastics are much better than of epoxies, with

Changing the insulation material results in a weight reduction of more than a factor of three while gaining superior mechanical performance. The material change reduces CO₂ emissions in the product life cycle by more than 50 percent [6]. All these improvements have been achieved by using advanced computer simulations.

Injection molding of thermoplastics is better suited for thin-walled parts in contrast to the bulky structures of epoxy components. Therefore when a material change

simulation results, modifications are introduced to the design and the next cycle of simulations is started. Based on the final results, the prototype of the part is manufactured and subjected to all tests required by standards.

With ABB's thermoplastic embedded pole, such an approach allows for a 50 percent decrease of the maximum stress level in the part → 5. By using the injection molding simulation the process settings are optimized and the material pressure in the mold cavity is reduced, which is important in this application as the overmolded vacuum interrupter was designed for low pressure casting process. With the computer simulations both the design of the thermoplastic embedded pole and its manufacturing process were optimized.

Liquid silicone rubber processing

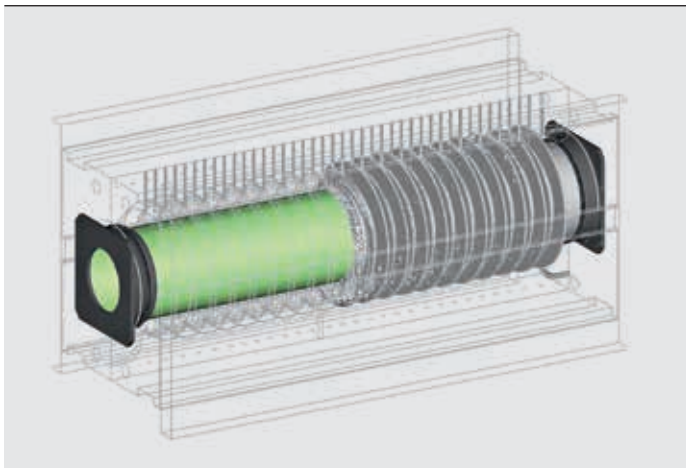
Silicone molding is another processing technology extensively used for producing electrical insulation in medium- and high-voltage power products like surge arresters, bushings, insulators and cable terminations. The excellent properties of silicone rubbers include high chemical and thermal stability resulting in the material hydrophobicity, UV stability as well as good flash-over and erosion resistance [7, 8].

Computer simulations allow engineers to look inside the injection mold for a complete picture of how the silicone rubber is processed.

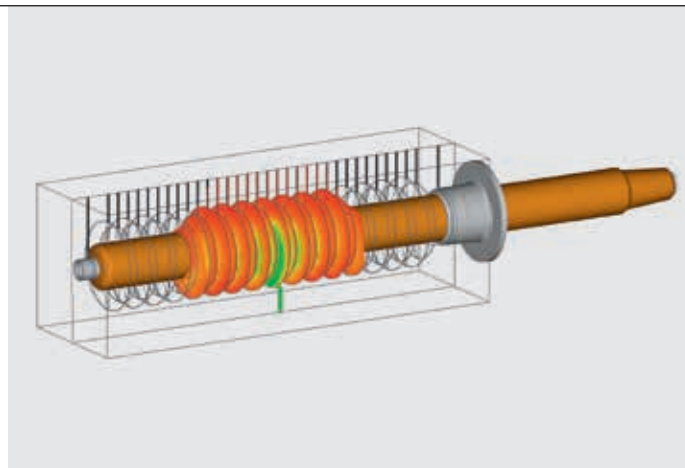
significantly higher stiffness and several times higher mechanical strength. The dielectric strength of the thermoplastics can also be superior. These strengths allow for significant reduction of the product weight and environmental impact.

ABB's PT1 embedded pole is an example of switching from epoxy to thermoplastics in ABB's medium voltage applications.

needs to be made for a medium or high voltage product, a complete redesign of the product is needed. The first stage of a redesign is to create the design ideas and then a draft design of the plastic part. Then the evaluation and optimization of the concept is carried out with simulation tools. In the mechanical analysis all the load cases to which the product is subjected during its operation are modeled. In parallel, the manufacturability of the part is verified with simulations of the injection molding process → 4. The dielectric performance of the design is checked with simulations of the electric field distribution. Based on



6a Flow pattern of silicone during mold filling



6b Course of curing process of silicone

Another factor influencing the properties of the silicone insulation is the material processing during the insulation manufacturing stage.

One of the possible threats connected with silicone molding is too high temperatures during the process that can cause degradation of the material properties. Good temperature control is even more important when taking into account the exothermy (heat generation) during the silicone curing, which might lead to creation of local hot spots. Besides that too severe temperature conditions can result in premature gelation of the silicone rubber and, consequently, in incomplete filling of the mold. Finally, incorrect design of the injection and ventilations systems can create air gaps during the mold filling, creating partial discharges in the operating product.

Computer simulations allow engineers to look inside the injection mold for a complete picture of how the silicone rubber is processed [9, 10]. For example, the silicone flow pattern, pressure growth, temperature field and silicone cure degree can be observed over time → 6. These results can be further used to recognize the potential problems connected with product design or its manufacturing process. Computer simulations can be applied to work out the improved product design and production process in shorter time periods and with lower investment costs.

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Further reading

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Life-cycle support

ABB's innovative service solutions for medium-voltage products

MARCO EGMAN, THOMAS ZURFLÜH – Innovative services being offered to customers today are changing the ways companies communicate, collaborate, and interact. And the way these smarter services are being delivered and used is also redefining customer support. Services increasingly focus on how customers are doing and what supports the customer's business process. Service at ABB is all about building relationships to support customers throughout the life cycle. With this approach the company is taking

the lead in offering innovative service solutions for its customers operating or working with medium-voltage assets. ABB service means close interaction between its service engineers and its customers as well as newly developed service solutions that seek to change the service approach to MV equipment. The primary areas with innovative approaches include asset support, switchgear and operator safety, and circuit breaker and protection relay upgrades and retrofits.

1 ABB's PowerCare matrix

PowerCare	Entry level	Level 1	Level 2	Level 3
Skills development services	Product training list	Product training	Application training	Coaching services
Emergency maintenance services	Single point of contact	Technical support with agreed response time	Callout support with agreed response time	Essential spare parts assessment and replenishing
Diagnosis and condition assessment services	Preliminary survey and documentation of installed base	Asset condition and risk assessment	Asset monitoring	Remote asset monitoring
Self-maintenance services	Installed base life-cycle status report	Manuals and instructions online	Online support for self-maintenance	File storage
Delivered maintenance services	Technical assessment on yearly basis report	Protection and control engineering services	Switching apparatus engineering services	Full switchgear engineering services

to documentation and information about all the assets, all increase the challenges.

In addition, demands on operators are growing because there are more changing load flows in power grids, harder budget limits for investments, a convergence of primary and secondary technologies, and more software that needs to be managed. Operators have to adapt their maintenance and modernization plans as equipment is pushed more and more to its limit and as new technologies emerge.

Web-based tool

Asset support services need to be fast, always available, easy-to-use and accessible through smart devices, eg, mobile phones and tablets. ABB has designed a powerful Web-based portal to meet these criteria, one that allows operators and equipment to become key assets of the MV network. With ABB's PowerCare the complete portfolio of

With ABB's PowerCare the complete portfolio of ABB service offerings are immediately accessible.

ABB service offerings is immediately accessible. A full range of services grouped in five areas – skills development, emergency, diagnosis and condition assessment, self-maintenance, and delivered maintenance services – are set up within the PowerCare framework. The

level of service is defined along four levels, with support content increasing with each level → 1.

Classic services such as training and assistance have been refined to meet today's requirements. However, the PowerCare portal also provides an expansive range of new advanced solutions. For example, the asset and risk assessment module gathers offline data using a tablet's app that enables nonintrusive site assessments. The module also provides reports and recommendations about the installed base and associated risks.

ABB's MyRemoteCare online remote monitoring solution enables the condition-based maintenance concept. ABB service engineers perform condition-based management by exchanging information with site operators on a virtual whiteboard, an instant messaging tool where questions, answers and comments are exchanged like sticky notes on a whiteboard. This allows both sides to look at the real-time condition of the equipment.

ABB's Clionet® Data Care is a service solution specifically designed to provide a secure place to store, update and recover protection and control equipment configuration and setting files.

Keeping safe

ABB's portfolio for safety includes a range of solutions targeting operators and equipment protection in all daily activities → 2. Fault prevention is the most important action asset managers can target to ensure full safety and availability. ABB provides clear solutions for mapping the source of all failures and associated risks.

ABB has a huge repository of knowledge, spanning not just its own branded products but also those of the numerous legacy companies acquired over time. With this wide range of competencies complementing its customers' own services and solutions, integration into the customer's asset operation process is possible at a variety of levels, all the while staying focused on the application of the products. The customer is then able to concentrate on its core strengths such as manufacturing goods or providing a service – for instance, running a manufacturing process – to its own customers. ABB service supports the customer so it can achieve its own operational goals.

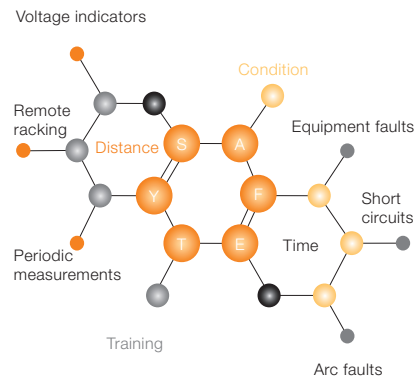
Operator challenges

For MV asset operators, having skilled and trained staff who can safely operate old and new assets is increasingly difficult. The growing complexity of installed-base, historically grown assets in different levels of the life cycle, along with different levels of know-how on old, mid-age and new assets, plus the need to have access

Title picture

Mobile devices are being used efficiently for customer support.

2 ABB's safety formula



Safety measures to prevent electrical hazards

An arc fault presents a significant risk as operators and equipment can be exposed to 20,000 °C plasma. ABB has developed an arc fault risk mapping software, which ABB service experts use to guide decisions concerning possible protection and mitigation solutions. The software also allows for analysis of the probability of the ignition of an arc fault and the possible consequences, and also facilitates the outlining and assessment of the arc fault risk picture. The software thus supports appropriate investment decision making.

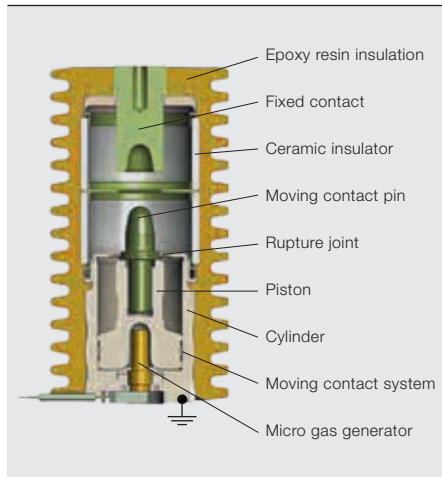
An analysis of the fault's probability and the relevant impact defines the anticipated level of risk. The most appropriate solution can be determined through an assessment. Depending on the risk level, solutions range from preventive maintenance to replacement and can include an REA arc protection system, the most advanced arc fault protection system on the market, or an ultrafast earthing switch (UFES™), the most powerful arc-fault-quenching system available → 3.

The other essential building blocks of the ABB formula for safety are highly trained personnel, remote circuit breaker racking systems and passive voltage indicators.

Retrofits

Equipment upgrades require the replacement of the circuit breakers and the protection relays once or more during the lifetime of the switchgear.

3 ABB's ultrafast earthing switch (UFES™) is the most powerful arc-fault-quenching system available.

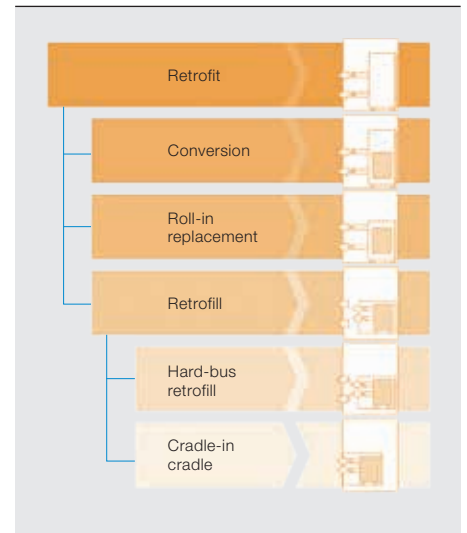


The challenge is to select the most appropriate circuit-breaker retrofit – from conversion to roll-in and retrofitfill – to meet specific customer requirements → 4. Assessing the existing equipment to check both the current condition and the future requirements is necessary to make the right choice. ABB asset and risk assessment tools apply the latest technologies to make this possible. Using 3-D scanning systems to make a full model of the installed equipment, regardless of age and brand, and transferring the relevant information to 3-D design tools is an excellent example of how ABB performs this kind of activity. The result is a quick and comprehensive site assessment completed under safe conditions.

In addition, a new generation of ABB engineering software is now available to support the implementation of new retrofit solutions. The software converts the gathered equipment data into a comprehensive feasibility study, which can then be made into manufacturing documentation. A process that in the past could take weeks of work now only needs a few hours.

OneFit represents the latest in ABB competence in the retrofit business. It is the most advanced retrofitfill solution available today, embedding all aspects in a unique design. The hard-bus retrofitfill model uses the most refined plug-in technology in order to ensure a quick and intrinsically safe installation. It fulfills all the requirements of the ABB formula for safety, allowing remote circuit breaker racking and it is ready made for integration with the MyRemoteCare monitoring and diagnostic system.

4 Circuit-breaker retrofit solutions



MV products are in continuous operation to ensure a stable, reliable and safe flow of electricity to power an enormous range of processes. With the service solutions provided by ABB the successful design and implementation of MV applications is guaranteed, regardless of whether the application is powering a manufacturing process in a factory, switching a substation in a distribution grid, or protecting an electric marine power propulsion system.

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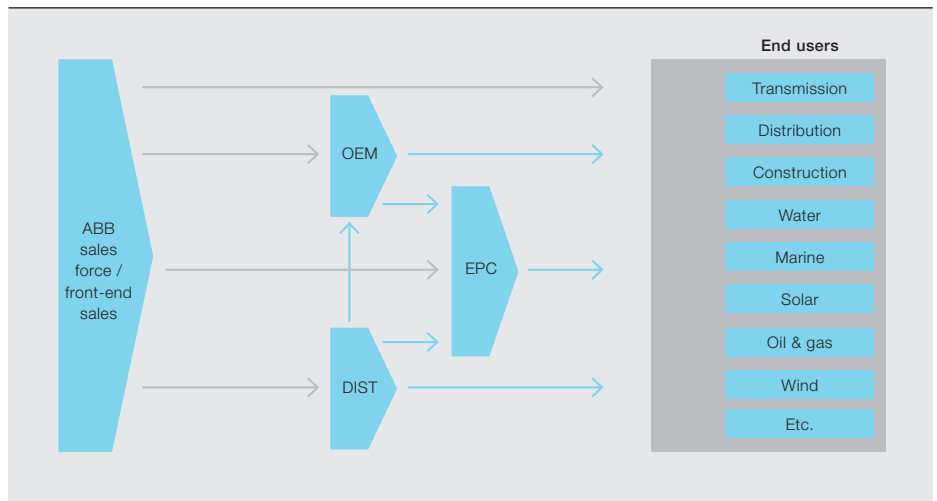


Pulling together

OEM partnerships are a vital element of ABB's customer value chain

NICOLE KOEPPEN – ABB sells a good number of its products directly to the end user. But this is not the only strategy to sell products: It can be very effective to build tight partnerships with third parties, especially OEMs (original equipment manufacturers) in order to create additional channels to bring goods to market. The combination of ABB's product expertise and the OEM's detailed knowledge of segments, application sectors, experience and local conditions can be very effective. ABB is creating high-value customer partnerships with OEMs that provide a comprehensive product portfolio, partner programs and cooperation models that embrace MV products and systems.

1 A multichannel approach maximizes market coverage.



– Distributors (electrical wholesalers/distributors, technical distributors and resellers) → 1

The path an ABB product will follow to reach the end customer will vary according to the end customer's requirements or even the nature of the third party itself. In essence, the third-party channels allow ABB products to become available or be assembled, engineered or serviced. OEMs, in particular, are a vital element in building and developing ABB's customer value chain.

OEM channel strategy

ABB's engineering, manufacturing and logistics capabilities combine with the detailed local market knowledge and exper-

example, the demand for local solutions is being driven by the need for flexibility and speed. Local manufacturers are, therefore, expected to grow in number. Further, many of these are supported by the government's preferential treatment aimed at boosting the local economy.

Given these market trends, ABB defined three strategies:

- Extend market reach and grow the number of OEM channel partners
- Leverage the complete ABB portfolio
- Develop OEM programs

ABB is committed to helping OEMs create high-value customer partnerships by providing a comprehensive product portfolio, partner programs and cooperation models that embrace MV products and systems.

Traditionally, ABB has a good standing in the OEM channel business and one of ABB's key strengths is the ABB brand itself. This comes with a reputation for technical leadership, quality and reliability. By incorporating ABB products as core components of OEM solutions, a pull effect is generated that is highly valued by partners and leveraged by them.

Over the last 12 years, ABB has made progress with the OEM channel business. For instance, ABB is now the leading supplier of MV circuit breakers to OEMs – and this represents only one product category in a portfolio that con-

ABB's medium-voltage (MV) power products business has a long history of working with OEMs. This type of cooperation started in the early 1990s with the supply of MV circuit breakers to MV switchgear manufacturers and has subsequently expanded significantly. The OEM channel has become a key element within ABB and is embedded in its multichannel sales strategy.

Multichannel strategy

ABB's market strategy is based on customer needs and buying behavior. Depending on the particular market segment and application, end users have different demands with respect to integration, engineering, availability and competencies, so different channels are utilized to meet their individual needs. This is called a multichannel marketing strategy.

The various sales channels can be categorized into direct and indirect (third-party) sales channels. The latter include:

- OEMs
- EPC (engineering, procurement and construction) entities

Title picture

ABB places great emphasis on creating high-value relationships with OEMs as channel partners. How does this work for MV products and what are the mutual benefits?

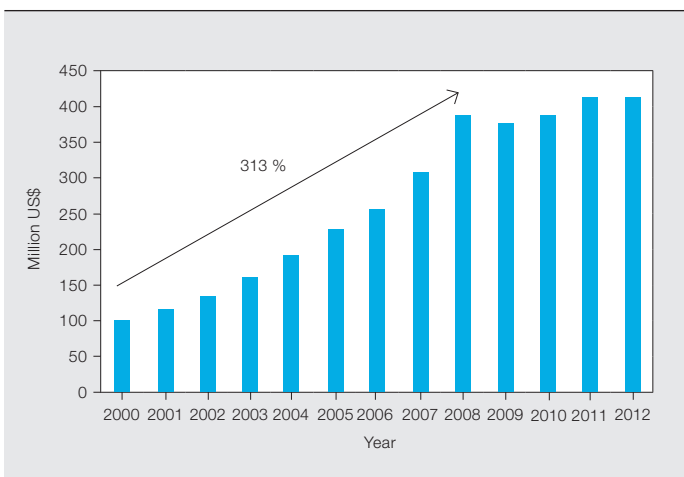
The OEM channel has become a key element within ABB and is embedded in its multichannel sales strategy.

tise provided by OEMs and panel builders to help drive sales across the world.

OEMs are active in various market segments and application sectors, so they differ significantly in terms of their scope and the value they add. ABB's OEM customers include electrical panel builders and compact secondary substation (CSS) manufacturers, for instance.

Also, in recent years, the market has become more fragmented, with requirements varying by market segment. For

2 The growth path: development of MV-related business with OEMs and distributors



The strategic intent is to position ABB as a reliable and consistent partner for OEM channel partners and to build long-term commitment based on a win-win relationship.

stitutes the most complete offering available on the market. ABB shares the latest products and offerings with OEMs to enable them to offer state-of-the-art technologies and gain a competitive advantage over local rivals.

The focus on channel business is a motor for ABB's success and growth – ABB grew the MV-related channel business for OEMs and distributors by 313 percent over the last 12 years, for example → 2.

The strategic intent is to position ABB as a reliable and consistent partner for OEM channel partners and to build long-term commitment based on a win-win relationship. The implementation of a dedicated regional OEM development and OEM product support organization has been part of this endeavor and it is planned to further strengthen the local OEM channel organization in the coming years. Further, ABB offers engineering and technical support, as well as extensive training programs and tools designed to assist channel partners. ABB develops OEM programs to meet partners' demands and aims to establish simple and effective processes to ease cooperation.

ABB's strict adherence to safety and reliability extends to its OEM partners, and sustainable and energy-efficient solutions enable partners to offer end users improved performance and lowered environmental impact.

OEM value chain business model

ABB's focus on OEMs aims to build on synergies between the breadth and quality of ABB's portfolio, and the particular strengths of OEMs in market sectors → 3.

3 The OEM value chain business model



In addition to the brand and technology advantage, ABB also strives to provide strong support to OEM channels and this is becoming increasingly important as a differentiator. ABB has tailored a business model that provides flexibility for channel partners to choose where in the value chain they want to position themselves. Based on this model, ABB has developed a series of modular OEM partner programs in which ABB combines its product offering with a technical support program as part of a holistic approach that meets an OEM's requirements for different markets and segments → 4.

The OEM partner program is a foundation upon which to develop a strategic partnership with OEMs. It consists of four pillars:

- ABB know-how and technical support
- A comprehensive ABB product portfolio
- Cooperation models
- The value added by the OEM

ABB know-how and technical support enable the OEM to introduce a product based on an ABB design in a very short time and with minimal investment. The transfer of technology consists of technical drawings, training, tools, configurators as well as access to testing facilities that allow OEMs to share their experience and concerns with ABB product experts.

The ABB know-how transfer and technical support for the specific OEM partner programs are managed by dedicated OEM product support organizations.



The first strategic agreement based on the value chain business model was made in Europe in 1998 for air-insulated primary switchgear. The cooperation enabled ABB to increase its market coverage by approaching a previously inaccessible market segment, and this partnership is still operating successfully. In fact, it has recently been extended by adding OEM partner programs for gas-insulated primary switchgear, outdoor circuit breakers and secondary switchgear.

So far, in the MV area, ABB has developed OEM partner programs for:

- Primary switchgear (IEC and ANSI)
- Secondary switchgear
- Indoor and outdoor switches
- Outdoor MV circuit breakers

The selection and qualification process is a key element of a successful implementation of the OEM partner program. The selection process ensures the suitability of the OEM partner for the different OEM partner programs, while the qualification process guarantees a consistent product quality during the cooperation period.

OEM cooperation models

OEM partner programs are supported and regulated by specific cooperation models covering all the legal aspects of a strategic partnership like responsibility, liability, commercial conditions, etc.

- Supply and support agreement: ABB provides the products, from simple equipment to complete switchgear. ABB logos, names and type tests are applied to the supplied products.
- Channel cooperation agreement: ABB offers a commercial partnership for a specific business segment. This

agreement is applicable for any product and OEM.

- License cooperation agreement: ABB grants a license to a third party to produce ABB products. ABB provides the technology transfer and type tests for the product. The OEM will use its own logo and ABB's product brand.
- Technical cooperation agreement: ABB provides the technology to a third party to produce an ABB product. The OEM will use its own logo and product brand name. The type test needs to be repeated by the OEM.
- Authorized value provider: ABB authorizes the OEM to use the registered ABB branding "ABB authorized value provider" on collateral documentation such as catalogs, brochures and business cards.
- Powered by ABB: ABB authorizes the OEM to put the registered trademark "Powered by ABB" on their products, which means that the OEM product contains ABB equipment.

Since 1998, more than such 80 partnerships have been established worldwide. The target is to extend the OEM partner programs outside of MV power products to embrace the complete power product portfolio. This will further strengthen ABB's leading position as a first choice for a partnership.

Kuwaiti OEM

In 2012, ABB received a \$10 million order, via its OEM channel partner IEPC, from Kuwait's Ministry for Electricity and Water (MEW) for vacuum circuit breakers (VCBs type VD4) and panel accessories. This was a major inroad into the Kuwaiti market, which has traditionally

been almost completely closed to foreign manufacturers. Signed in September 2012, the contract is the culmination of more than four years of work spent establishing a strategy with IEPC, gaining experience, and optimizing costs and technical solutions.

IEPC is Kuwait's leading OEM for low- and medium-voltage power distribution equipment and its knowledge of the local market and technical requirements was combined with ABB's expertise in electrical distribution to win the order.

The order was Kuwait's largest ever for its distribution network and ABB's successful bid will see VD4 type vacuum circuit breakers installed in 500 distribution substations along with switchgear panels and other equipment provided by IEPC.

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Innovation in motion

How ABB's MV product portfolio is evolving to address market needs

SAMI RAITAKOSKI – The medium-voltage power world is in the midst of a challenging, and yet exciting, time. As the world becomes increasingly more reliant on secure electricity supplies, pressure on the power distribution industry to deliver is also increasing. The ways in which electricity is being generated, transmitted and even used are changing – that is the challenging part. The exciting part comes from the new technologies and solutions being created to meet those challenges. In order to respond to the evolving needs of today's global power distribution market and to help support power and utility companies, ABB is pushing the boundaries of technology, establishing itself as a trusted partner, and expanding its global footprint through new growth opportunities. Continual, proactive advancements allow ABB to offer a wide range of new products and solutions for its customers to enhance grid reliability, meet rising demands for electricity with increased energy efficiency, and improve productivity.

1 Advantages of ABB's medium-voltage offerings

- Breadth of offering
- Depth of technology
- End-user segment diversity
- Global view and presence
- Vast installed base
- Market-leading positions
- Local market focus and footprint
- Ability to leverage scale
- Multiple channels to market
- People and domain competence

2 Market drivers in the medium-voltage segment arena

- Urbanization
- Energy-intensive industries
- Remote bulk generation from renewables
- Distribution generation
- Cost pressures
- Aging infrastructure

3 ABB's innovative plug-and-play modules avoid lengthy shutdowns of rail services for the installation of coupling stations.



ABB has been in the business of medium-voltage power distribution for well over a century, providing utility, industrial and commercial customers with safe, reliable technologies. Over this time the company has been a constant pioneer both of the technology itself and of its applications. The huge portfolio of products and services available now for current conduction, electrical insulation, switching operations, protection, control and interruption is a testament to this pioneering spirit. Today's portfolio includes 66 product lines in 34 sites in 27 countries. And this portfolio is evolving so that ABB can offer its customers solutions that are more efficient and reliable, safer, smarter, more environmentally friendly, and easier to engineer, install and operate → 1.

Change factors

A variety of issues are driving the product and service solutions for maturing medium-voltage markets → 2. More people in cities means more pressure on city

Title picture

The world is becoming increasingly dependent on secure electrical supplies. How is ABB helping its electrical distribution customers meet the challenge?

grid modernization, extension, etc. An aging population means there are fewer personnel who are knowledgeable about old and new equipment. There is a growing complexity of installed-base, historically grown assets in different levels of the life cycle, along with different levels of know-how on old, mid-age and new

An evolving global economy demands that ABB continually seek ways to better serve its customers.

assets. This in turn increases the need for immediate access to documentation and information about all the assets. And these all bring about safety and reliability issues.

Utilities are looking for smarter, more sophisticated solutions to modernize their networks. In addition more environmentally friendly solutions are being asked for.

Renewable energy sources, distributed generation and increasingly complex and demanding networks of power consumers are also factors.

Smart technologies

As part of modernizing their networks, medium-voltage operators are looking for

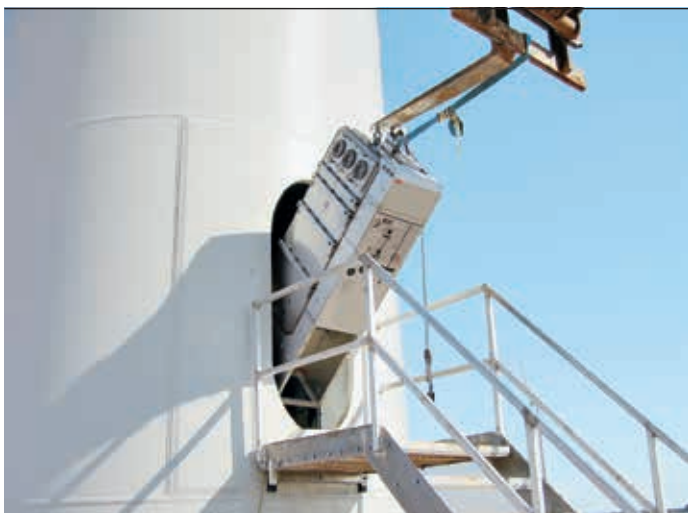
products equipped with sensors and IEDs. To address the demand for smart switchgear, ABB has developed the UniGear Digital product family for primary substations. It is

based on an optimized integration of current and voltage sensors into MV switchgear, combined with the latest IEDs and IEC 61850 communication. Through improved levels of automation and communication in substations central operators can optimize grid operation.

World view

Different regions and countries around the world can have needs specific to

4 SafeWind, ABB's tailor-made switchgear for wind turbines, is the slimmest medium-voltage switchgear on the market.



that particular area. ABB is addressing its global reach into new markets with products under ABB's "country for country"/"region for region" approaches. A unique offering for the distribution market in India is an example of this.

ABB combined its well-proven and reliable switchgear, circuit breaker, and protection and control technologies to create the ZN1 for the unique needs of the distribution market in India. ZN1 is a primary distribution switchgear with features such as a compact construction, low maintenance design and an internal arc withstand current rating of 26.3 kA for 1 s, which is unique in this sector. The design is the perfect solution for applications in India's construction, automotive, water distribution, textile, rail transportation, pharmaceutical and data center industries. Designed and developed in India, ZN1 offers easy installation and maintenance. The smaller footprint and compact design reduces switchgear room dimensions resulting in additional energy savings due to reduced air conditioning and lighting requirements.

Adapting to industries

Installing coupling stations in a traction power supply system can be a costly, complex and time-consuming process that causes disruptions to passenger and freight services. ABB has been able to take its innovative plug-and-play module system to the rail industry in order to avoid lengthy shutdowns of rail services → 3.

The solution comprises medium-voltage modules that are preassembled and factory-tested to enable speedy erection

5 ABB service engineers develop innovative customer service solutions.



on-site. Available for either indoor or outdoor installation, the modules can be erected and commissioned overnight to avoid disruption to busy daytime rail schedules.

The main components – circuit breaker and disconnecter switches – are made by ABB and have long and proven track records in railway environments. The cir-

The ABB drives channel partner network offers global quality with local availability.

cuit breaker has an innovative design that enables the entire module to be transported simply and efficiently in a standard ISO freight container.

Swiss Federal Railways and South Africa's Gautrain are among the first to embrace this solution.

Switchgear alternative

Environmental concerns are also driving the development of a new generation of power distribution products. In order to meet the increasing demand for solutions with lower environmental impact, ABB developed SafeRing Air, a compact ring main unit that uses dry air as an alternative to the traditional SF₆ insulating gas.

ABB also recognizes that wind and solar sources present a more complex energy flow for distribution equipment to handle and is extending its global footprint by meeting the unique needs of the renewable energy sector.

For example, SafeWind, ABB's tailor-made switchgear for wind turbines, is the slimmest medium-voltage switchgear on the market and small enough to fit through the narrow doorway of the turbine tower → 4. Designed specifically to meet the switchgear requirements of wind turbine manufacturers for compactness, safety and flexibility, SafeWind is a complete range of secondary distribution gas-insulated switchgear for onshore and offshore applications in the global wind power market.

Safety issues

Safety is addressed throughout ABB's entire portfolio. In the face of the internal arc-fault hazard present in medium-voltage switchgear, ABB is continually looking at its portfolio for safety solutions targeting operators and equipment protection in all daily activities. To that end, ABB has developed a highly sophisticated arc-fault risk-mapping software, as well as an ultrafast earthing switch (UFEST™), which is the most powerful arc-fault-quenching system available.

Customer service

An evolving global economy demands that ABB continually seek ways to better serve its customers. Service innovation is a new and significantly improved service concept that ABB is implementing. Service innovation is about shifting the

6 The ABB drives channel partner network takes the sales, support and service business to the customer.



focus away from just providing solutions and instead focusing on the job the customer is trying to get done. ABB strives to better understand and translate customer needs into viable products, solutions and services → 5. One example is a powerful Web-based portal from which the complete portfolio of ABB service offerings are immediately accessible.

Additional partnerships

Building close partnerships with third parties is another way of offering fast, effective and reliable sales support to its customers. To that end ABB has an international drives channel partner network. For instance, ABB's product expertise combined with original equipment managers' (OEMs) detailed knowledge of segments, application sectors, experience and local conditions has been very effective. ABB is creating high-value customer partnerships with OEMs that provide a comprehensive product portfolio, partner programs and cooperation models that embrace MV products and systems → 6. The ABB drives channel partner network offers global quality with local availability. It is a network of authorized partners that takes the sales, support and service business where it belongs – close to the customer.

Working with the customer

ABB understands that close collaboration with the customer during product development leads to well-received products that fulfill the customer's requirements. Collaboration agreements continue to be an important factor in product development. One recent example is the extensive undertaking to develop a

better solution for detecting transient and restriking earth faults. Part of this effort involved the cooperation of selected power utilities in order to test and develop the new earth-fault protection functions. A new algorithm was developed in close cooperation with the Vattenfall utility in Sweden, where it was tested with actual disturbance recordings representing a wide variety of network and fault conditions. ABB's continued collaboration with its customers to develop future products helps to ensure increased power availability.

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