

# The perfect cast

## Development of ABB's new generation of outdoor reclosers using advanced simulation methods

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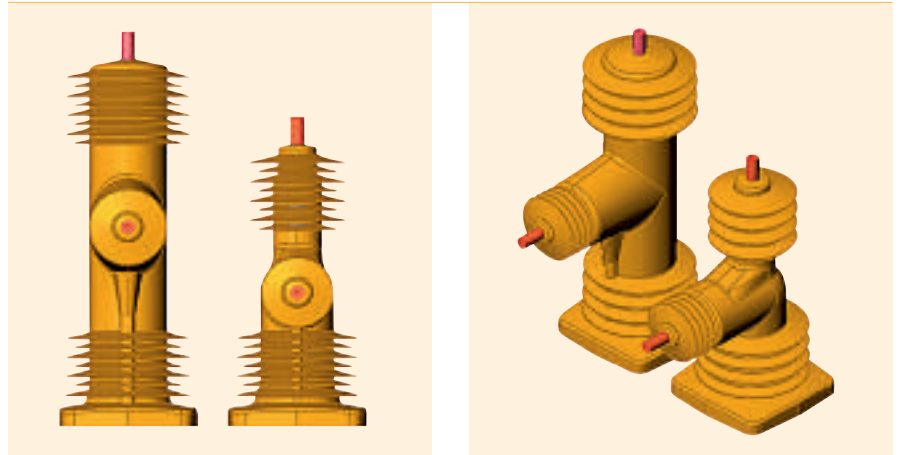
ABB began to re-design its OVR (Outdoor Vacuum Recloser) in 2000. Using an international design team, the end result is a "small" power switch principally used in power distribution networks.

The integrated current sensor and communication units permit the use of remote control and the immediate location and identification of faults. A compact lightweight housing, developed in the course of the re-design process, facilitates fast and easy installation of the device as a unit. It consists of a housing with three poles, a drive, position indicators and a control and remote communication unit.

The main component of the recloser is the vacuum interrupter chamber, encapsulated in outdoor epoxy resin. The chamber enables all necessary switching operations. Such chambers are capable of completing a very large number of switching cycles without the need for maintenance, and present no ecological threats. The resin-molded enclosure reduces the number of moving components and extends maintenance intervals. It also improves the resilience to acts of vandalism. Polyurethane has been replaced as an insulating material by Cycloaliphatic epoxy resin. This material is suitable for outdoor applications and ensures longer fault-free operation of the device.

Two types of devices were developed: One for operational voltage levels ranging between 15.5 and 27 kV; and the second one for voltage levels up to 38 kV. The higher voltage levels required a different type of vacuum chamber, and hence larger dimensions. The structure of the OVR, however, for both types remained basically the same **1**.

**1** New types of outdoor vacuum reclosers.



The design was supported by simulations for electric field strength and distribution, molding and curing processes and for the assessment of mechanical deformations and stresses occurring during these processes.

### Application of numerical methods in the development of epoxy products

The popularity of simulation techniques is shown by their use in a wide range of applications.

The simulation tasks for ABB's OVR re-design project included:

- Simulations supporting the electric system design (dielectric properties, electric field strength and potential distribution).
- Simulations of the reactive molding process (mold filling, the curing process, post-curing), thus providing important data such as temperature distributions, curing degree, potential stresses and deformations.

The simulations to determine the distribution of electric fields were completed before the simulation of the reactive molding process was begun.

The reactive molding simulation (based on the Automated Pressure Gelation (APG) process) used techniques developed by ABB Corporate Research during the RAMZES project.

RAMZES (ReActive Molding ZERo-defects Solution) is a 3-D computer simulation tool that provides information to identify what happens during the critical molding and gelation process. The data can be applied to the design of the mold itself, and to key variables like resin temperature, injection pressure, mold temperature scheme, position of inlet channels and the initial temperature of internal parts. This information helps overcome common molding problems, such as premature gelation, undesired weld-lines and air traps.

These simulation methods are based on the commercial, three-dimensional FLUENT software. They incorporate two models: the *Macosko* viscosity model and the *Kamal* curing kinetics model - both describing the thermosetting material (epoxy resin).

The process of developing a new product usually involves several evaluation cycles. This is costly and usually increases time to market, and it does not eliminate the possibility that faults may be discovered later.

Simulation is now successfully employed by many companies to optimize design, shorten the development process and improve the manufactur-

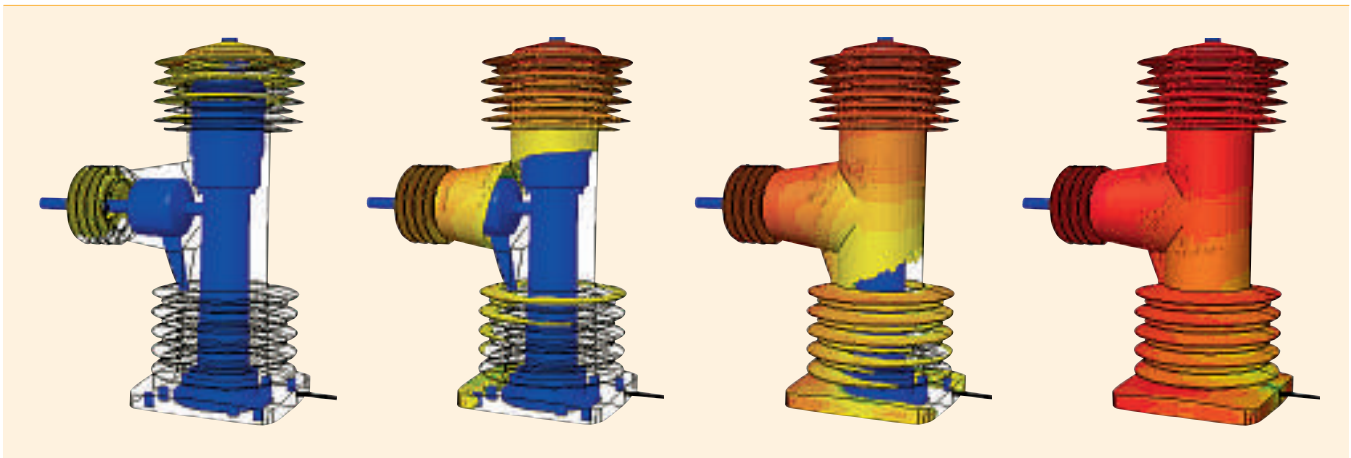
ing process. Of course no simulation can fully replace physical testing, but powerful simulation tools can significantly speed up the process and improve fault detection.

This line of thinking was applied when ABB decided to develop the new generation of outdoor reclosers. In fact, the design process relied heavily on simulations. Simulation determined

the dielectric performance of the device and helped select the best geometry. It also supported the manufacturing process by simulating the filling of the mold and the curing of the epoxy.

The result: a very reliable device in a very short time to market!

2 Curing propagation (38 kV OVR).



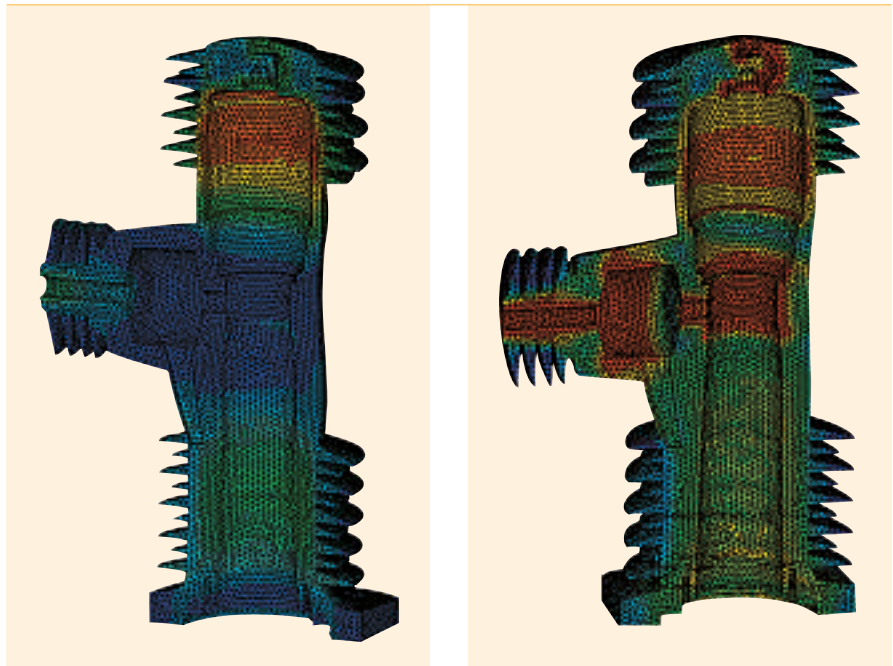
The commercial ABAQUS software rounded off the simulation phase by modeling chemical shrinkage using the models developed by ABB Corporate Research.

The simulation software results helped determine important parameters for the overall manufacturing process, from mold filling, through the curing process to the final heat processing of the product. The simulation took into consideration the full complex structure of the process (injection of liquid material, polymerization, chemical and thermal shrinkage, heat exchange, stress build-up).

The mold filling process was generated with the use of a visualization method. When this phase of the process was analyzed, it was possible to identify and locate areas in which the mold might remain unfilled so that the positions of the injection inlets could be adjusted.

One of the most important simulation results of the reactive molding process was a description of the temperature distribution and curing propagation 2.

3 Stresses in a recloser.



The results obtained by using the FLUENT software were transferred to ABAQUS, and structural analyses were performed. These covered the time in which a component is left in the mold (approx. 150s) and the duration of the

entire cooling process (approx. 33 hours). Sample stress distribution in the component is shown in 3.

To optimize the manufacturing process, several simulation runs were

performed using varying parameters sets.

Production began after the process parameters had been set in accordance with the simulation data **4**.

This 3-D simulation approach had the following advantages:

- A shorter development period for the product.
- Reduced costs of mold design.
- Shorter manufacturing cycles.
- Improved process efficiency.

#### Test Procedure

Extensive prototyping tests were performed to ensure the technical functionality of the products and to meet the quality requirements in the course of mass production. The most important included the electrical **5a**, mechanical and visual tests and inspections. Prototype tests were performed in accordance with ANSI C37.60 at several testing laboratories in Mexico, Sweden, Italy and Germany.

Stable operational voltages and currents, the surge-current performance

and the ability to switch-off capacitive and inductive loads are the most significant advantages of the recloser.

Randomly selected devices were checked for their performance under varying temperature conditions **5b** – down to  $-60^{\circ}\text{C}$  – to verify their resist-

**Suitable APG molds can now be prepared based on reliable simulation data with relatively few design modifications. In addition, manufacturing processes and tools are easier to control.**

ance to crack formation. The rate of temperature change applied was  $10^{\circ}\text{C}$  per hour.

#### The future

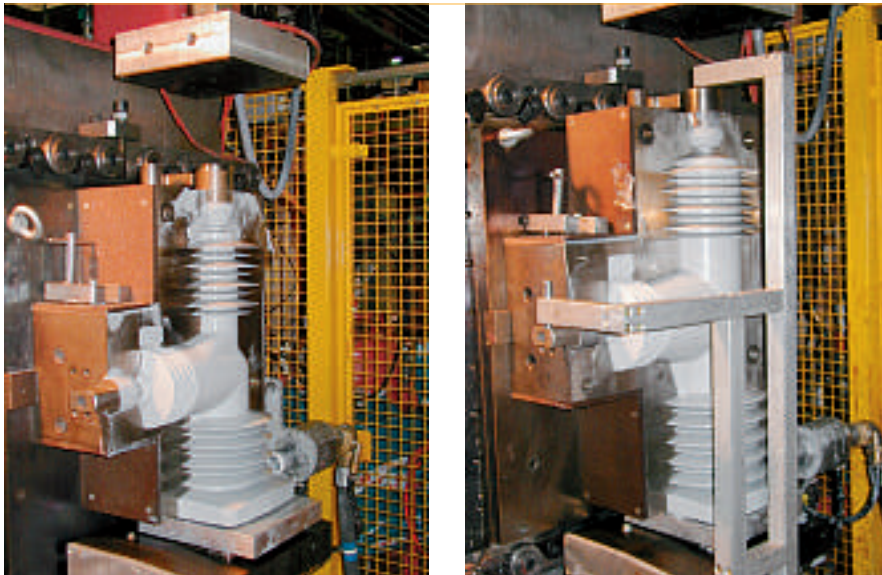
The modern design incorporates the results of advanced simulation techniques that: make the development process significantly shorter; optimize

the design; and minimize the risk of defects occurring in the manufacturing process.

Suitable APG molds can now be prepared based on reliable simulation data. The application of a special tool surface coating method (nanotechnology-Nanogate) improves the APG manufacturing process. After special treatment, a cleaned mould surface is covered with a nano-lacquer – characterized by strong chemical bonds with the substrate – and thus forms an excellent base-layer with antistick properties.

The knowledge obtained by transferring the simulation data to the APG mold design process implies a significant method improvement or even a “quantum leap” that revolutionizes design processes. The number of design faults have been significantly reduced and manufacturing processes and tools are now easier to control.

**4** Casting of the reclosers (ABB Calor Emag Mittelspannung, Ratingen).



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**5** Testing of reclosers: electrical tests (a) and low-temperature tests (b).

