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MAJOR TRENDS



AMASIS: Getting electric arc simulation right

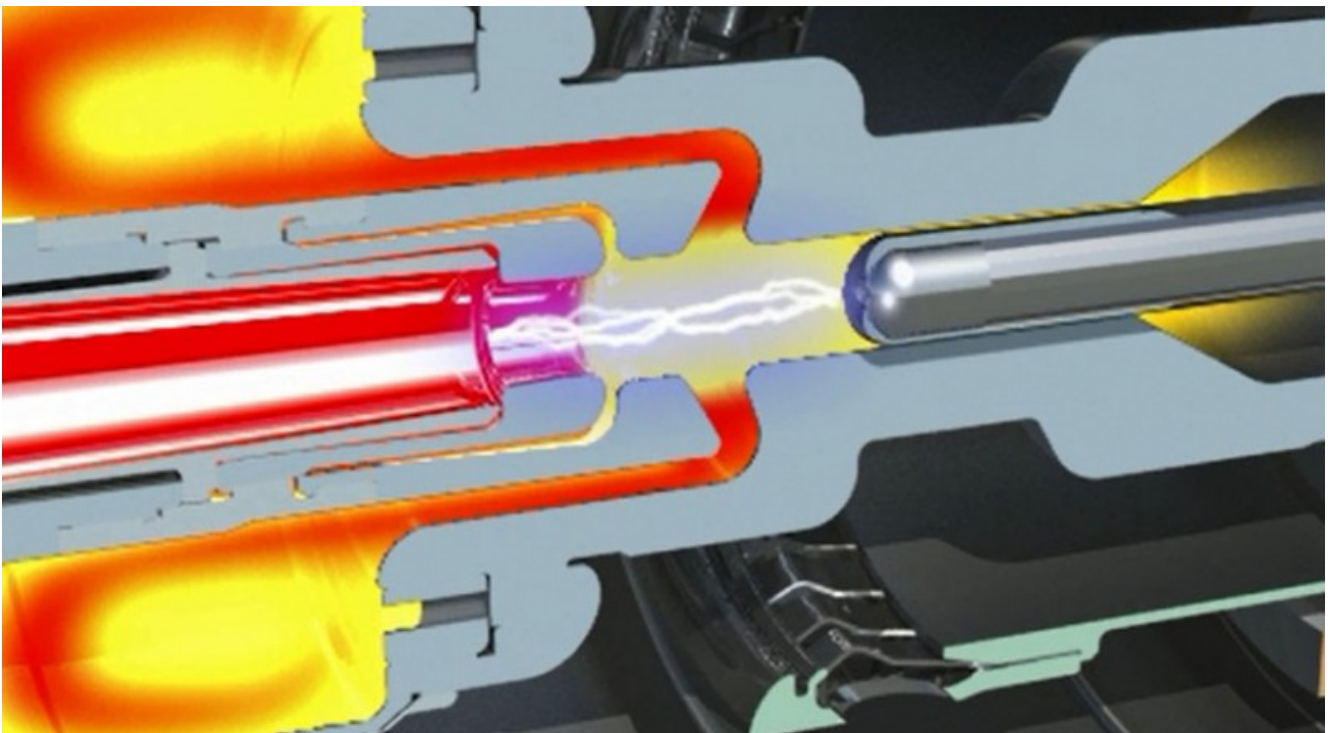
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 CIRCUIT BREAKERS  GIS

Short-circuit current breaking inside a circuit-breaker chamber involves phenomena ranging from plasma fluid dynamics to mechanical destruction. A multi-physics macroscopic simulation tool can be used to model what is happening to improve circuit-breaker design.



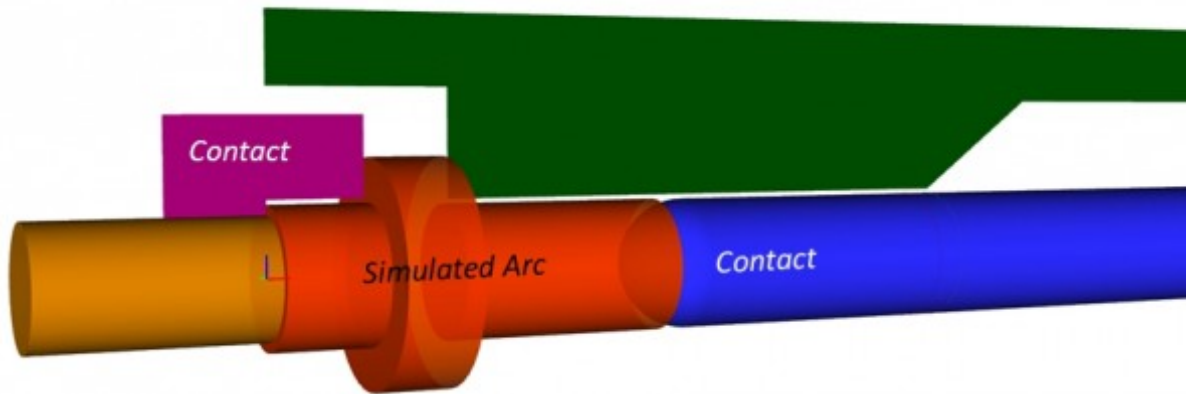
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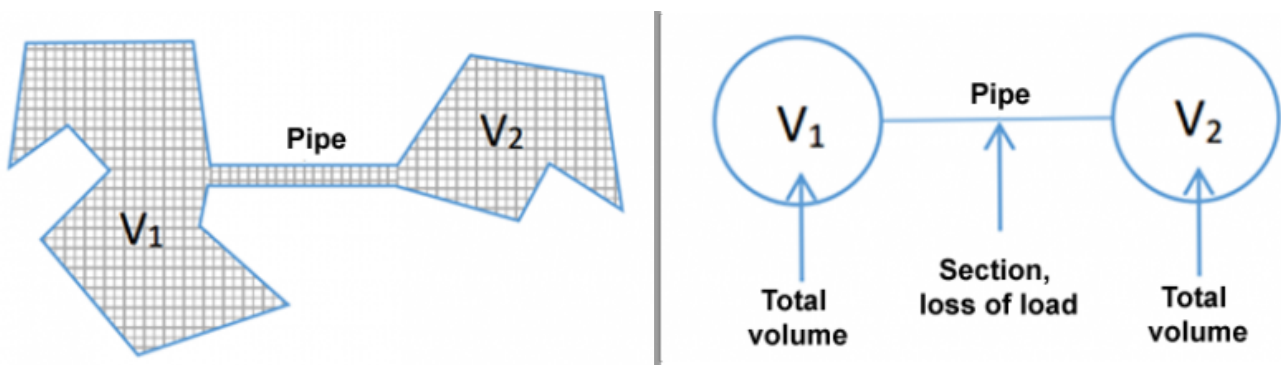
Modelling is very important for circuit-breaker development since it makes it possible to study different configurations before tests and investigate specific behaviour. A modern high voltage circuit breaker is a lot easier to describe than to model: separate two contacts in a gas with good dielectric properties; an arc forms and carries the current; blast this arc with the gas to cool it and quickly extinguish the arc. The difficulties come from the fact that we are dealing here with a complex system where multiple nonlinear physical processes are occurring and interacting simultaneously, including phase changes, convection, conduction and radiation. And all that in a small module with moving parts where arc temperatures can reach 20,000 °C and pressure can be over 100 atmospheres (10 MPa).

Five-minute simulations

Despite improvements in computing power and software, simulating precisely what is happening inside the circuit breaker is usually very time consuming. A new modelling approach from Alstom is changing that. AMASIS (Arc Model for AMESim Interrupting Simulation) is a macroscopic model of the core of the circuit-breaker chamber that can perform a simulation in only five minutes.



Sébastien Silvant, Alstom Grid Innovation Group Manager in the Circuit Breaker and Bays Department, explains what “macroscopic” means in this context: “Macroscopic tools give us a general view of the physical parameters that indicate the quality of the arc blasting, such as overpressure in the thermal volume, gas flows, arc voltage and so on. It’s a broader picture than more detailed ‘microscopic’ models; you only have average temperatures for instance, although in reality these can vary. But it is fast.”



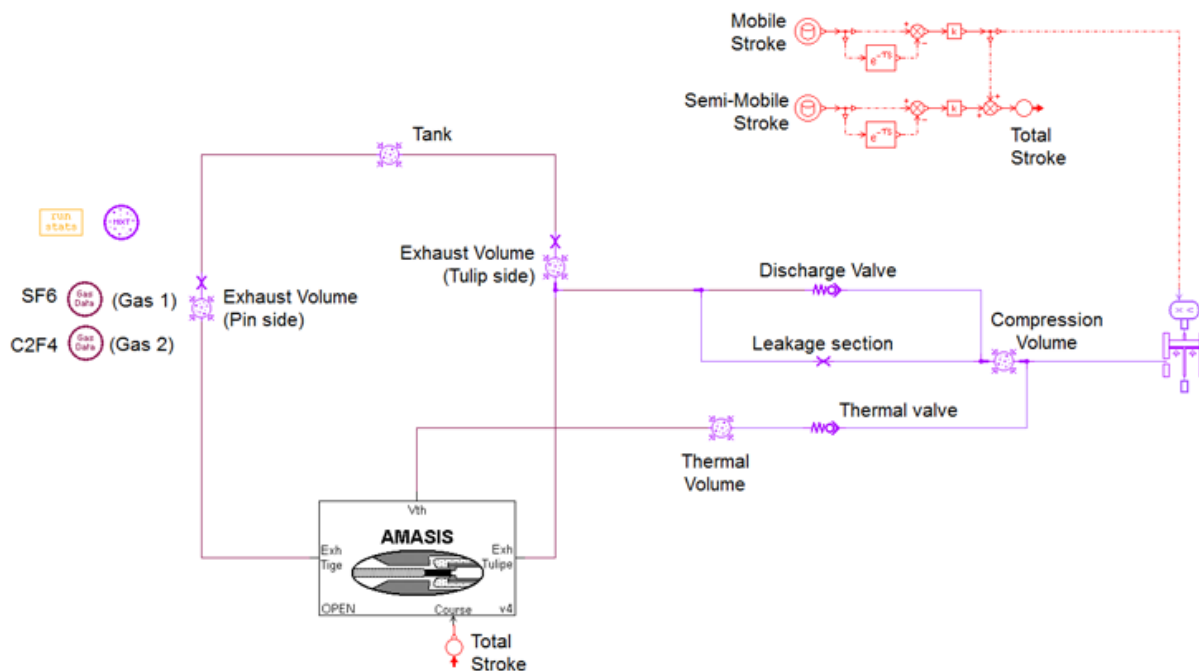
On the left : Microscopic modeling ; On the right : Macroscopic modeling

The AMESim part refers to the commercial software for modelling multi-domain systems from LMS Imagine.Lab on which the Alstom application is based. In AMESim, models are described using nonlinear time-dependent analytical equations that represent the system’s hydraulic, pneumatic, thermal, electric or mechanical behaviour. Standard AMESim modules are used to model the different parts of the circuit breaker other than the core, with AMASIS concentrating on the zone of influence of the electric arc itself.

Modelling the joule effect

“The electric arc is a source of energy generated by the joule effect, and AMASIS quantifies this energy, using a number of user-defined parameters,” explains Silvant. “These cover a wide range of domains – instantaneous current, kinematics within the chamber, a set of parameters to describe the geometry of the circuit breaker, and data concerning the gas.” The gas is usually SF6 at present, but given its high global warming potential, Alstom has developed g3 (green gas for grid), an eco-friendly alternative. The properties of this new gas can be introduced in AMASIS modelling.

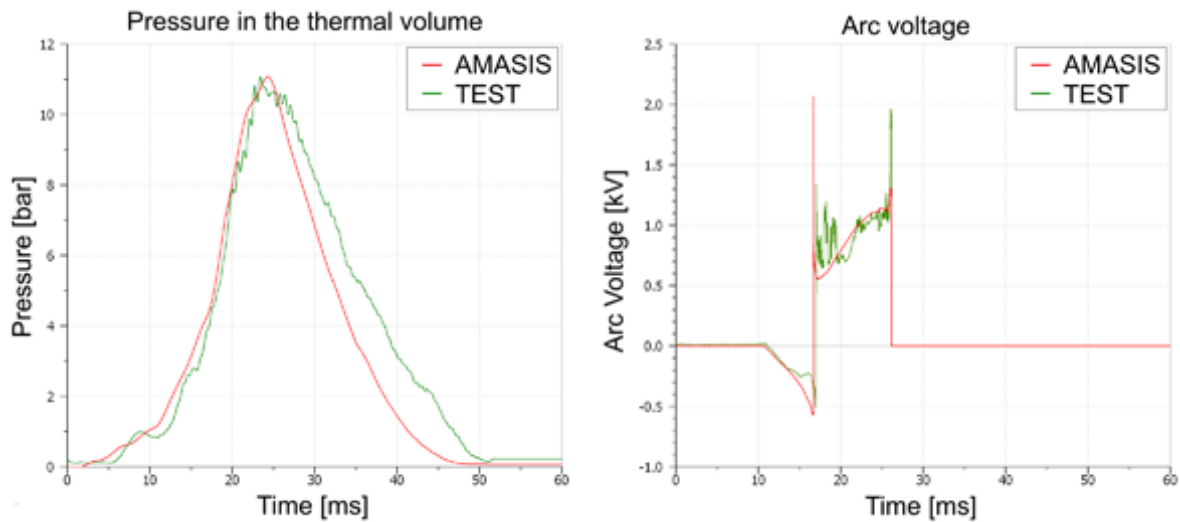
The energy balance of the electric arc shows how the joule energy is dissipated. AMASIS models the different radiation and convection phenomena that contribute to dissipating this energy, and also the variation in arc volume due to the difference between energy generated and dissipated. The energy dissipated by radiation is assumed to be partly absorbed by the gas, with the rest contributing to the erosion of polytetrafluoroethylene (PTFE) parts. The mass that is ablated is assumed to be injected, with a specific enthalpy corresponding to that of grey PTFE, directly into the space between the electrodes.



Measuring up

Does it work? As Silvant puts it: “The practical application of all this theory is to build a better circuit breaker. So, we compared our simulations against our large database of actual measurements in various devices of

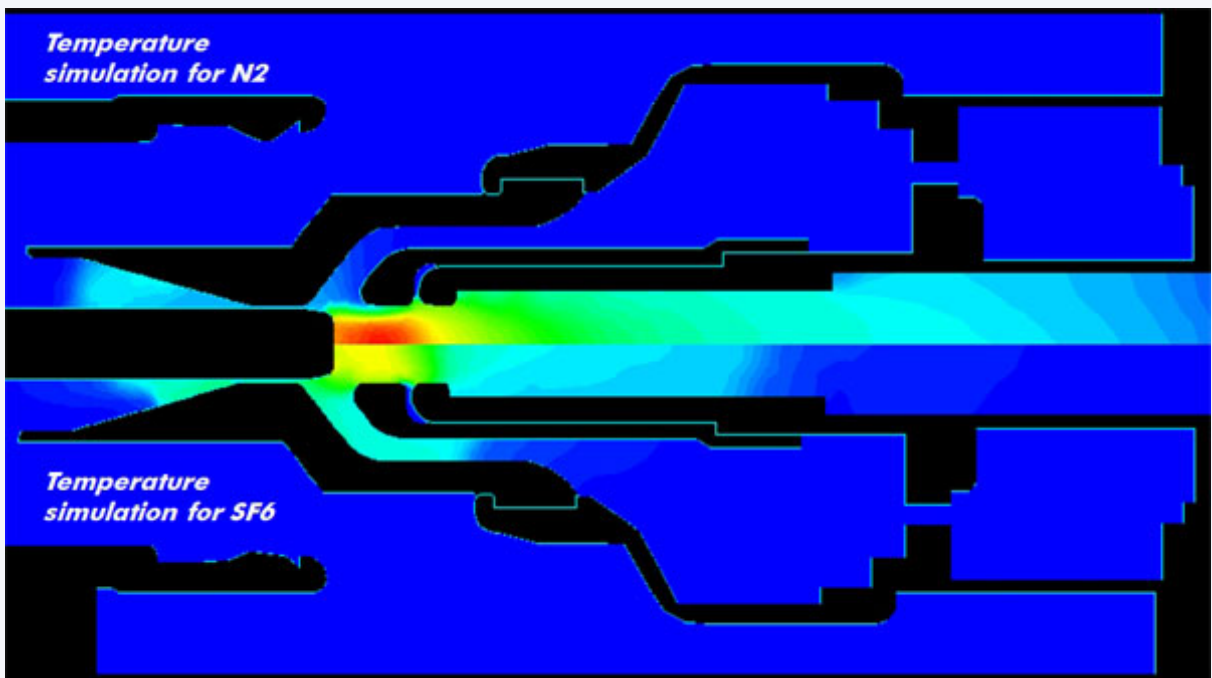
overpressure, arc voltage, the quantity of nozzle material ablated, and the new diameters after ablation. This allowed us to fine-tune the models so that our calculations soon converged towards the measurements, and to strike the right balance between measures of overpressure and measures of arc voltage, and also between the measurements for the whole set of devices used for calibration.”



MC3: Getting down to detail

AMASIS has the great advantage of allowing parametric studies to be done quickly, but as its “macroscopic” label suggests, it gives a broad picture. This is useful for pre-dimensioning a device, but the results then have to be refined, which is where MC3 comes in. This is a finite elements-method design and analysis software suite based on a physical model of the operation of interrupters and fuses on high voltage electric networks. The challenge is to model the highly complex plasma phenomena occurring in the interaction of a high-velocity dielectric gas jet with an electrical current. MC3 assumes local thermodynamic

equilibrium in the device and deduces mass, momentum and energy. The viscous effects of the gas in the presence of an arc are negligible at high temperature and high velocity and do not need to be taken into account. An energy equation includes radiation and heating effects and another set of equations is used to calculate the electromagnetic fields. Gas ionisation, which has nonlinear behaviour, is deduced depending on the temperature and pressure.



MC3 integrates the geometric representation of the configuration, and numerical solution of the flow, energy and electromagnetic field equations. A series of distinct modules allows the designer to create models for devices, specify their operating characteristics, and simulate the transient phenomena to extract the pertinent parameters.

MC3 accuracy and productivity are far superior to more traditional approaches involving multiple tests.

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Sébastien Silvant

Alstom Grid – Innovation Group Manager

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