# Studying and modeling electric arc under the effect of high magnetic field


UNIVERSITÉ Clermont Auvergne

Ecole doctorale Sciences Pour l'Ingénieur

LPC Particules pLasmas Univers applications — Laboratoire de Physique de Clermont

## ALMURR Jessica, ROCHETTE David

*Université de Clermont-Auvergne, Laboratoire de Physique de Clermont, Socomec.*

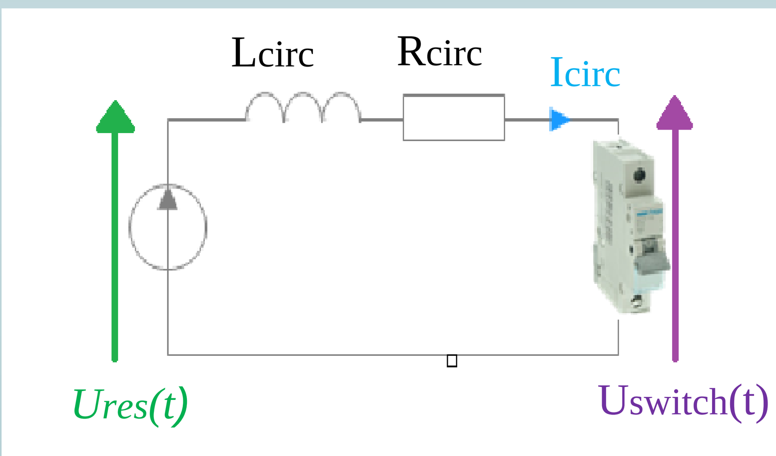

# Introduction

Owing to the fact that DC circuits become more in demand, researches have been focused lately on developing DC low voltage switches. In order to do that, it is necessary to have detailed knowledge about DC breaking technique. The latest consists on creating an electric arc between the electrodes of the switch while they are opening, and increasing its voltage so that the arc's potential is greater than the supplied voltage.

Because of the very complicated processes, the developers have been relying mostly on experimental investigations so far. On the other hand, the increasing performance of computers allows simulating more and more details of the switching arc.
In this work, we are going to present an experimental set-up where the displacement of an electrical arc between two parallel arc runners is studied with high-speed imaging, voltage, current pressure and magnetic measurements. In parallel, a two-dimensional (2-D) simulation model is described, which is based on the differential equations for fluid and electromagnetic physics, the so-called MHD equations.

# Methods

## DC breaking concept for a RL circuit



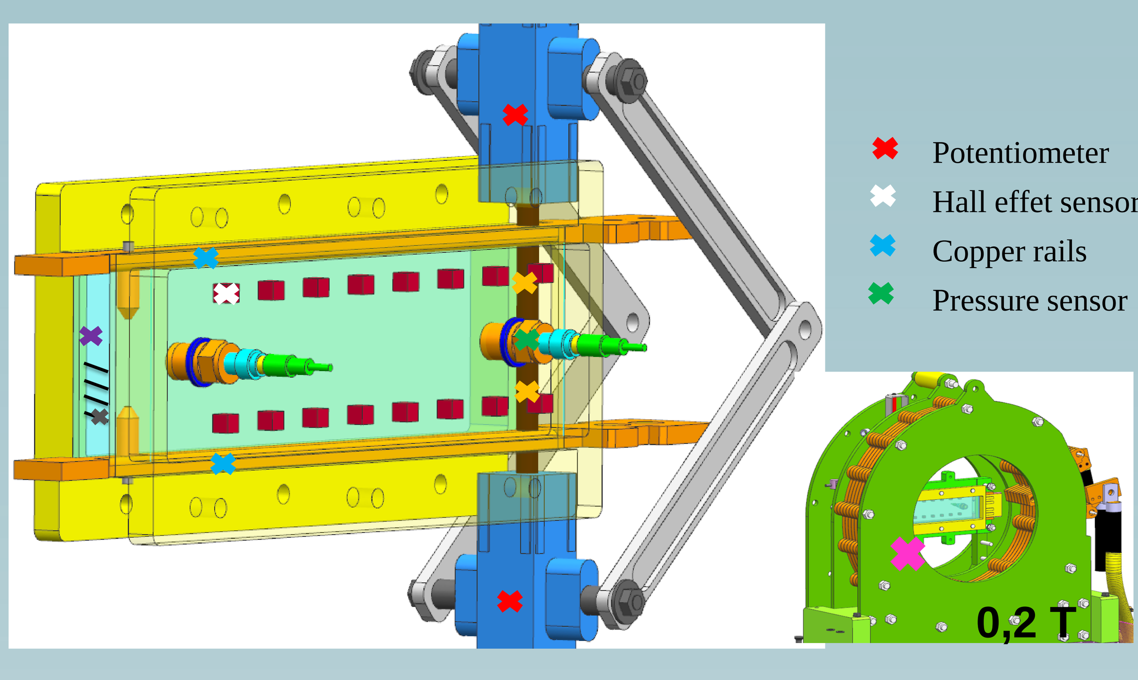

$Ures(t) = Rcirc*Icirc + Lcirc\,\frac{dIcirc}{dt} + Uswitch$

$$\frac{dIcirc}{dt} = -\frac{Rcirc}{Lcirc}Icirc + \left(\frac{Ures - Uswitch}{Lcirc}\right)$$

$Uswitch(t) = r*Icirc + Uarc$

| | |
|---|---|
| $\frac{dIcirc}{dt} < 0$ To interrupt the current | $Ures - Uswitch < 0$ $Uarc > Ures$ We have to increase the arc voltage |

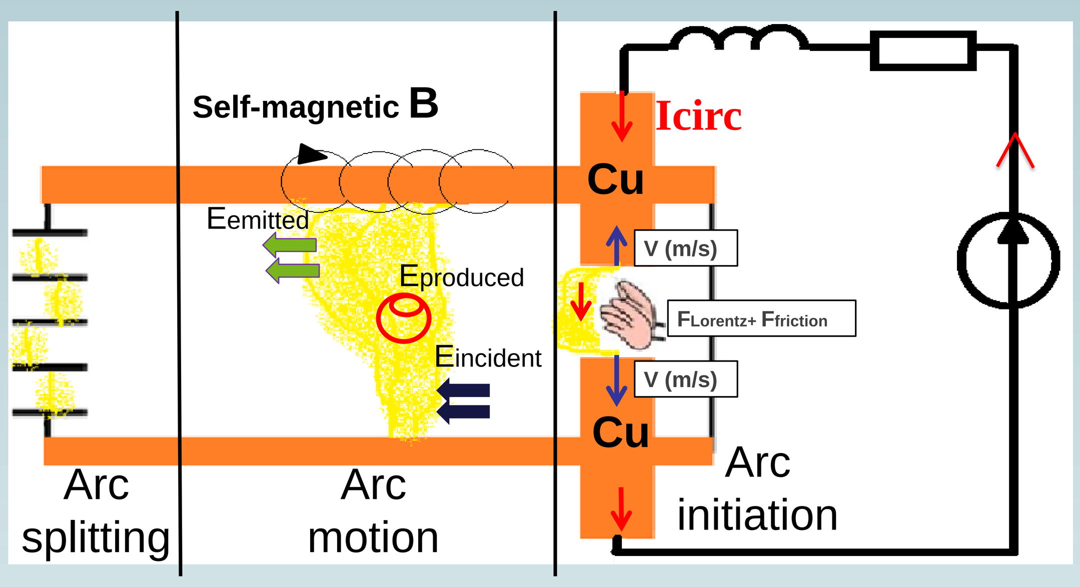
## Experimental settings for a simple arc chamber




- ✖ Potentiometer
- ✖ Hall effet sensor
- ✖ Copper rails
- ✖ Pressure sensor
- ✖ High speed camera
- ✖ Copper moving contacts
- ✖ Helmholtz coil
- ✖ Splitter plates

## 2D time dependent electric air arc model

**Energy Balance**
- Joules heating $J^2/\Gamma$
- Radiation $4\pi\varepsilon_N$
- Electron anthalpy $\frac{5}{2e}K_BTJ$
- Conduction $-\lambda\,\nabla T$

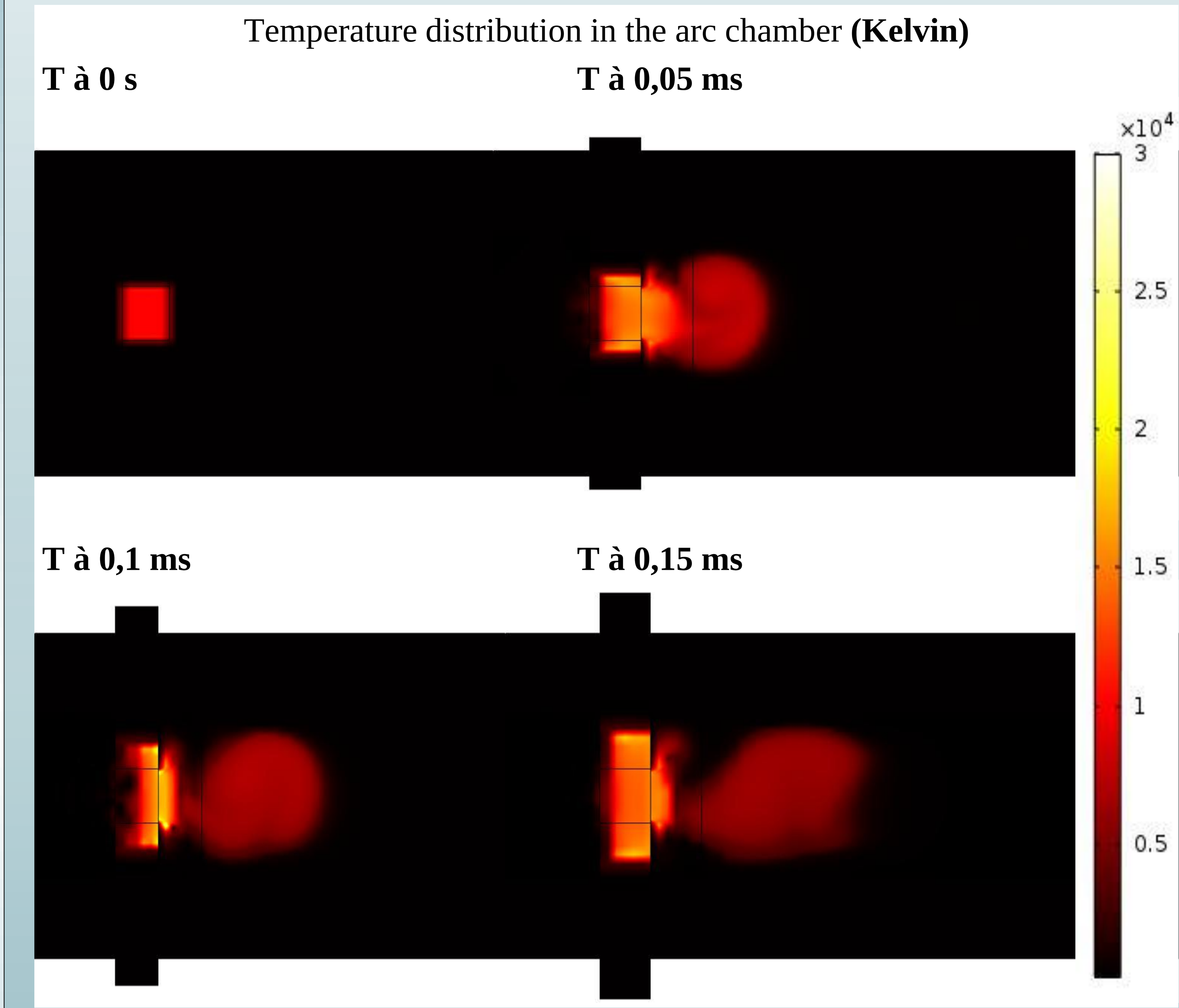



The system of magneto-hydro-dynamic MHD equations in the local thermal equilibrium approximation

- $\frac{\partial\rho}{\partial t} + \nabla(\rho\mathbf{v}) = 0$
- $\rho\frac{\partial \boldsymbol{v}}{\partial t} + \rho(\mathbf{v}.\nabla)\mathbf{v} = \nabla[-\mathbf{P}\mathbf{I} + \mu\left(\nabla\boldsymbol{v} + (\nabla\boldsymbol{v})^T\right) - \frac{2}{3}\mu(\nabla.\boldsymbol{v})I] + \mathbf{j}\times\boldsymbol{B}$
- $\rho c_p\frac{\partial T}{\partial t} + \rho c_p\,(\mathbf{v}.\nabla)\mathbf{v} = -\nabla.\,(\lambda\,\nabla\,T) + \left[\mu\left(\nabla\boldsymbol{u} + (\nabla\boldsymbol{u})^T\right) - \frac{2}{3}\mu(\nabla.\boldsymbol{u})I\right] + \mathbf{J}^2/\boldsymbol{\Gamma} - 4\pi\varepsilon_N + \frac{5}{2e}K_BTJ$
- $\mathbf{E} = -\nabla.\varphi$
- $\boldsymbol{j} = -\sigma\nabla\varphi$
- $\nabla\times\boldsymbol{H} = \boldsymbol{J}$

# Results

For a first approximation, a 2D time dependent model, for an air electric arc is choosen. A simplified geometry of the dimension 30x12mm is used. The copper rails are of 30 mm length and 3 mm width, the gap between them is 6 mm. The contacts open with a velocity of 10 m/s. The temperature distribution is presented which shows the shape of the arc during 0,15 ms.




The air arc in switches typically exists near atmospheric pressure; its temperature is usually of the order of 10 kK. So as initial condition a rectangle surface between the moving contacts with 10kK temperature is taken (T=0s) . The results show the arc elongation with the moving contacts after 0,05 ms, and its propagation in the chamber to the splitter plates during the time.

# Conclusions

A 2-D model for the simulation of the electric arc has been presented. It takes into account the gas-dynamic as well as the electromagnetic processes. With this model it is possible to simulate the motion of the arc in a simple arc chamber. First results of temperature distribution at different time steps have been presented. The elongation of the electric arc when the contacts open can be observed.
Moreover, an experimental set-up is presented. It is designed for both validation of the model and explanation of the measurements.
Furthermore, the results of an improved simulations as a 3-D models will be compared to those given by the experimental set-up in order to validate the model.

# Bibliography


1. Yi Wu, Mingzhe Rong, *Numerical Analysis of the Effect of the Chamber Width and Outlet Area on the Motion of an Air Arc Plasma*, 2008
2. Mingzhe Rong, Yi Wu, Qian YANG, *Simulation on Arc Movement under Effect of Quenching Chamber Configuration and Magnetic Field for Low-Voltage Circuit Breaker*, 2005
3. Frank Karetta and Manfred Lindmayer, *Simulation of the Gasdynamic and Electromagnetic Processes in Low Voltage Switching Arcs*, 1998
4. Manfred Lindmayer, Joachim Paulke, *Arc motion and pressure formation in low voltage switchgear*, 1996