



Compte rendu FSO 2015 pour l'Association Arc Electrique
Physic of Switching arc

Brno, République Tchèque

| Pierre Freton

<http://www.uvee.feec.vutbr.cz/conference/FSO/>



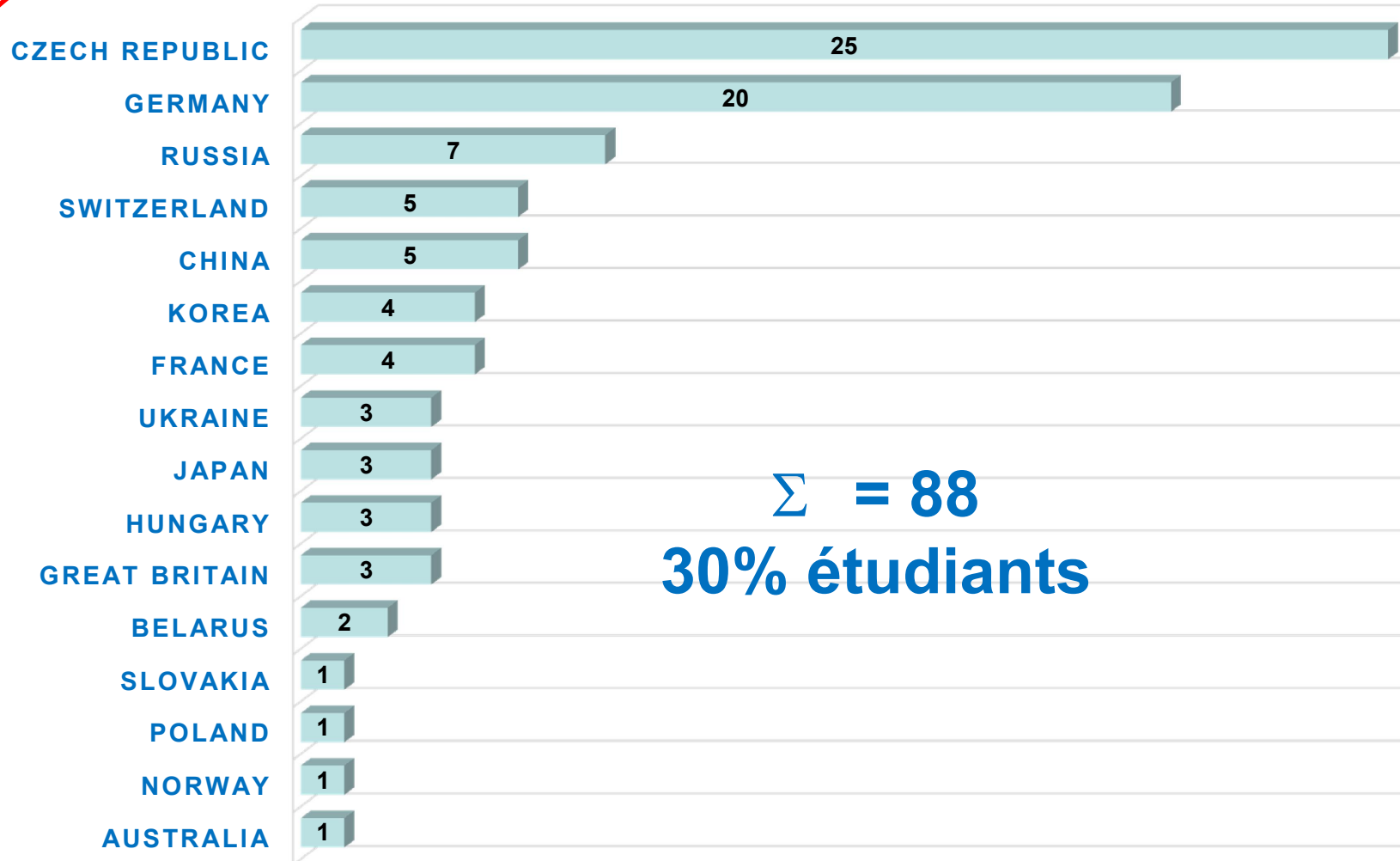
Lieu : Brno



Hotel Ski



Participants





Participants





Organisation

- ➔ 10 conférences invitées de 45 minutes
- ➔ 20 Conférences « thématiques » de 15 minutes
- ➔ 2 Sessions poster 43posters
- ➔ Publication dans le journal « Plasma physics and Technology »
<http://fyzika.feld.cvut.cz/misc/ppt/index.html>

4 grandes thématiques recensées

- **Disjoncteurs haute tension** (3 invited, 12 topical lec., 8posters)
- **Disjoncteurs basse et moyenne tension** (1/3/7)
- Protection (1/2/0)
- **Applications / divers** (5/3/28)

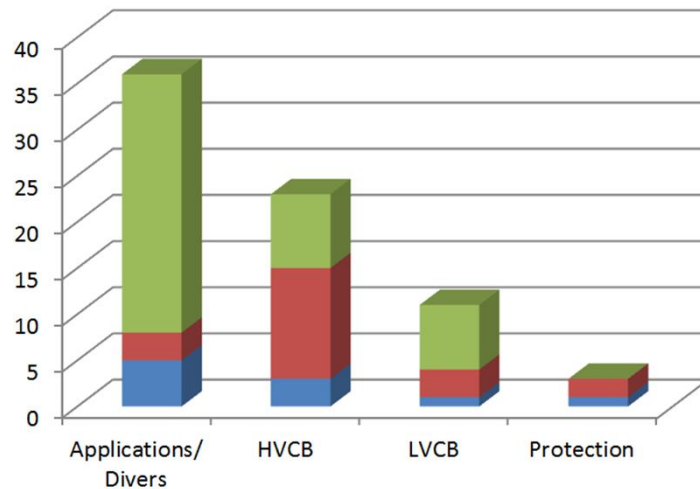


Thématiques

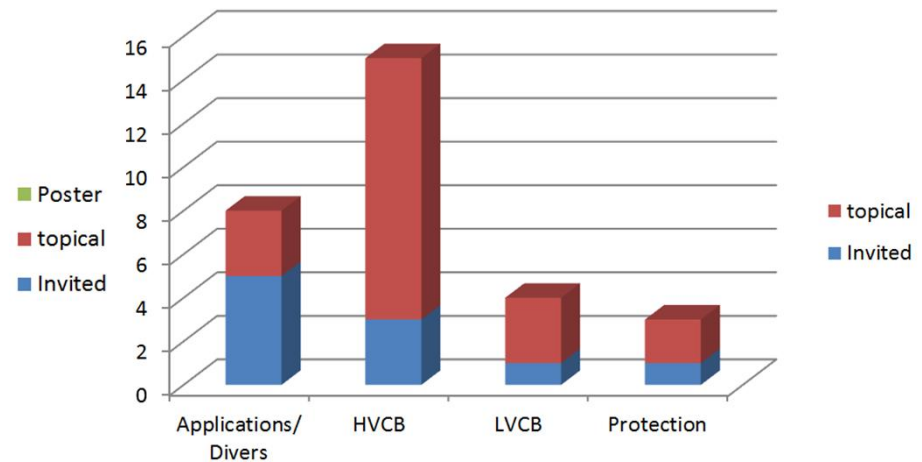
4 grandes thématiques recensées

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- Protection (1/2/1)
- Applications / divers (5/3/28)

Au total



A l'oral





Thématique disjoncteur haute tension

Conférences invitées

- J.Q. Zhang (UK) Modelling of Turbulent SF 6 Switching Arcs
- M. Seeger (CH) Future Perspectives on High Voltage Circuit Breaker Research
- Kosse (DE) Future Proof and Low Carbon Footprint Insulation for Switchgear

Lectures thématiques

- C. Leu (DE) Measurement of Electric Conductivity of Hot Gas in a SF 6 - Circuit Breaker Interrupting Fault Currents
- Ph. Robin-Jouan (FR) Detailed Investigation of Breakdown Prediction Models for High Voltage Circuit Breakers
- Reichert (DE) Studies on the Thermal Re-Ignition in SF 6 High-Voltage CB by means of Coupled Simulation
- J. Ostrowski (CH) Internal Arc CFD Simulation of Long Single Phase HV-Gis
- T. Ohtaka (JPN) Development of Prototype Low-Cost and High-Strength Fault Current Interrupting Arcing Horns for 77 kV Overhead Transmission Lines
- R. Methling (DE) Spectroscopic Measurements of Arc Temperatures in a Model HV Circuit Breaker
- S. Franke (DE) Spectroscopic Study of Arc Temperature Profiles of a Switching-Off Process in a Model Chamber
- J. Valenta (CZ) High Voltage Laboratory FEEC BUT Brno
- A. Petchanka (DE) CFD Arc Simulation of a Switching-Off Process in a Model Chamber
- P. Kloc (CZ) Optimization of 3-Band Mean Absorption Coefficients
- G. Madarász (HU) Arc Simulation at Shunt-Reactor Switching in H.V. Circuit Breakers
- P.G. Nikolic (DE) Design and Test of a Technology Demonstrator for a CO2 Filled Circuit Breaker with Two Heating Volumes
- P Robin Jouan, SF6 Alternative Development for High Voltage Switchgears

- L'auteur stipule que ce sont les modèles qui ont le plus évolué durant les 20 dernières années

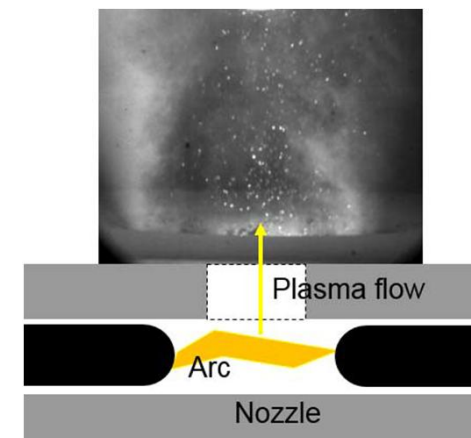
Seeger a répertorié les thématiques importantes pour :

- Rayonnement

- Souvent que du SF6
- Méthodes de résolution de la RTE
- De grosse différences dans les données suivant le sources, besoin de validation
- Pas de vapeurs métalliques pour le moment
- Comment réduire le temps de calcul

- Contact erosion and nozzle ablation

- Ablation du PTFE encore mal comprise
- Influence des vapeurs métalliques peu étudiées



- Turbulence

- Pour l'instant modèle rans
- Le mieux serait du 3D LES mais très couteux
- Importante au courant zero

- Ecart à l'équilibre

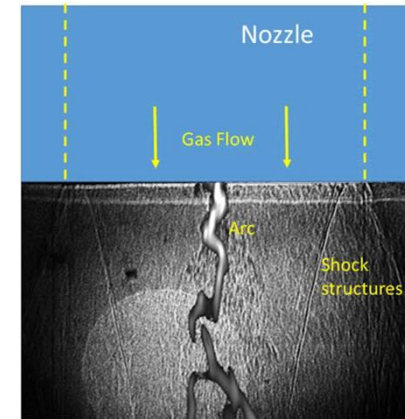
- Pas nécessaire à fort courant
- Important au courant zero
- Besoin d'une meilleure description théorique
- Quelques études expérimentales

- Claquages

- Problème de recouvrement diélectrique (streamer/leader)
- Réamorçage thermique

- Alternatives au SF6

- Nouveaux gaz



Conclusion : encore beaucoup de travail

Validation d'un modèle avec des mesures spectroscopiques

- Adaptation de la CL d'électrode poreuse
- Modèle dans SF₆, ablation PTFE, mesure prenant en compte absorption

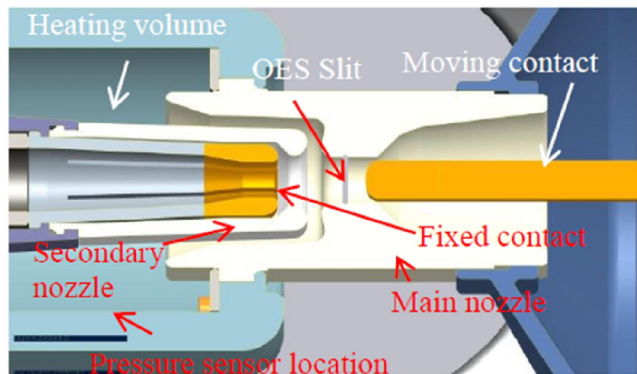


Fig. 1: The arc quenching area of the model chamber

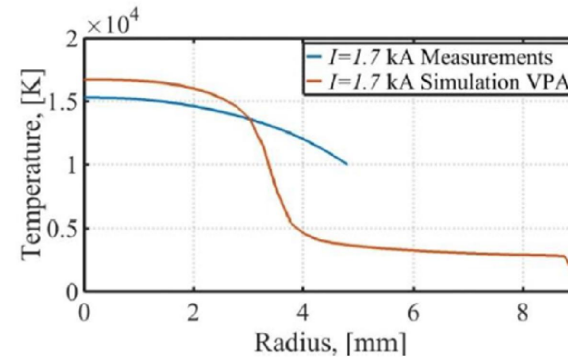
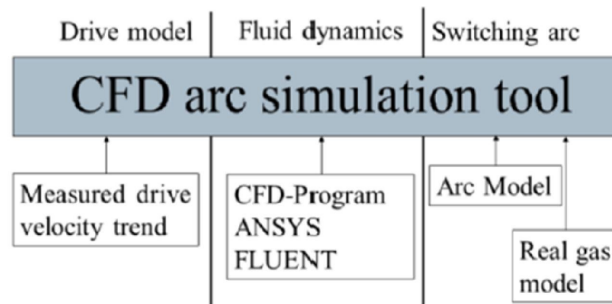
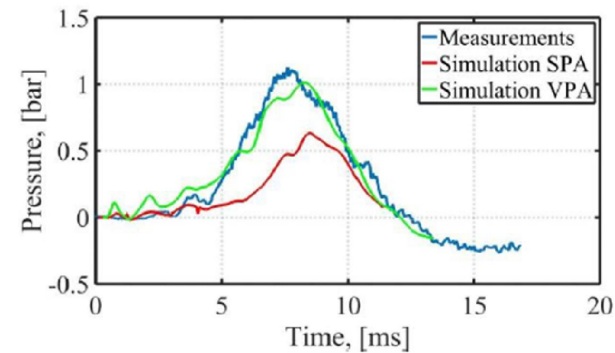
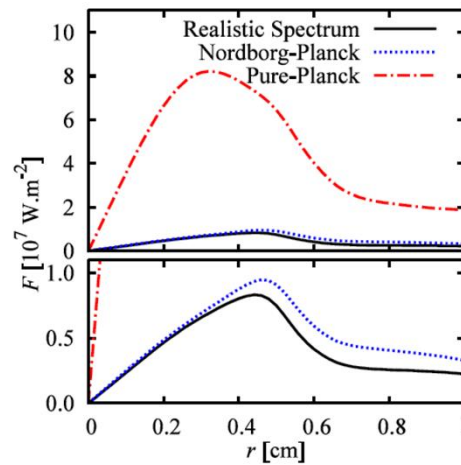
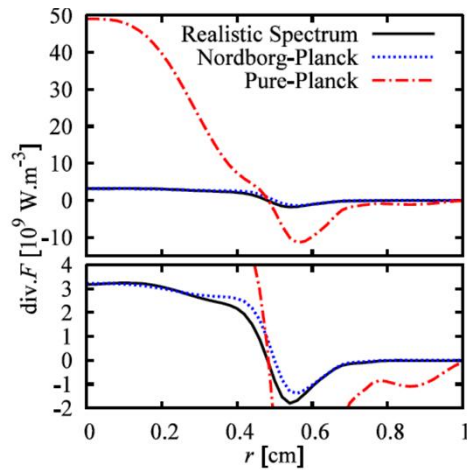
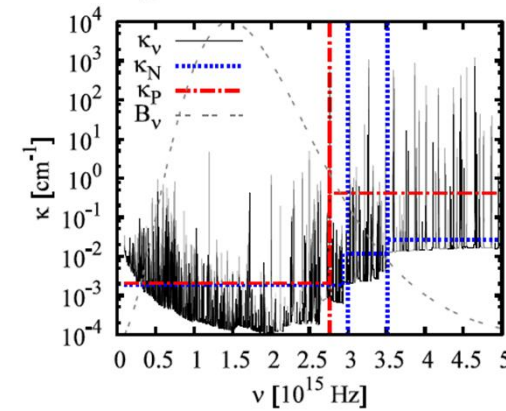
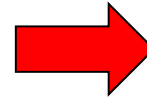
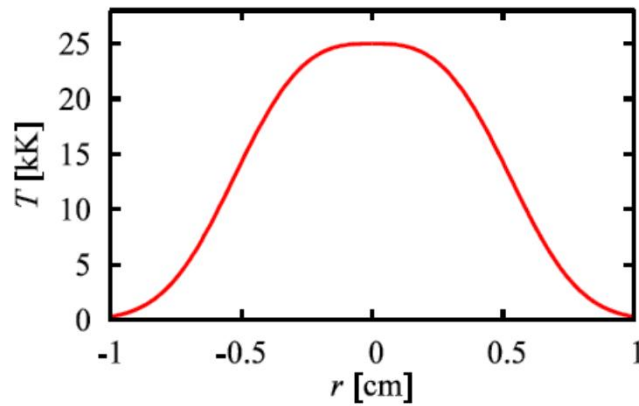


Fig. 7: Comparison of radial temperature profiles



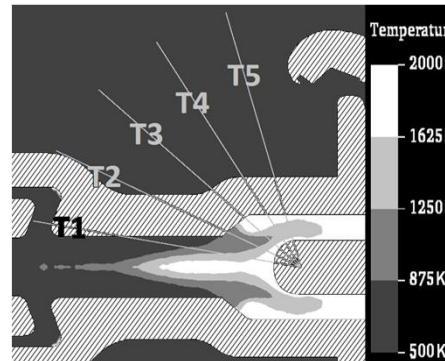
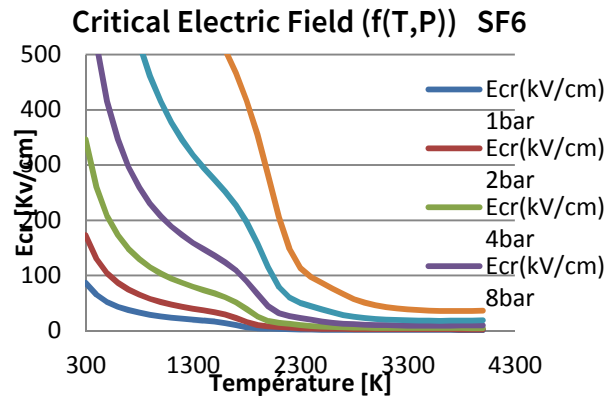
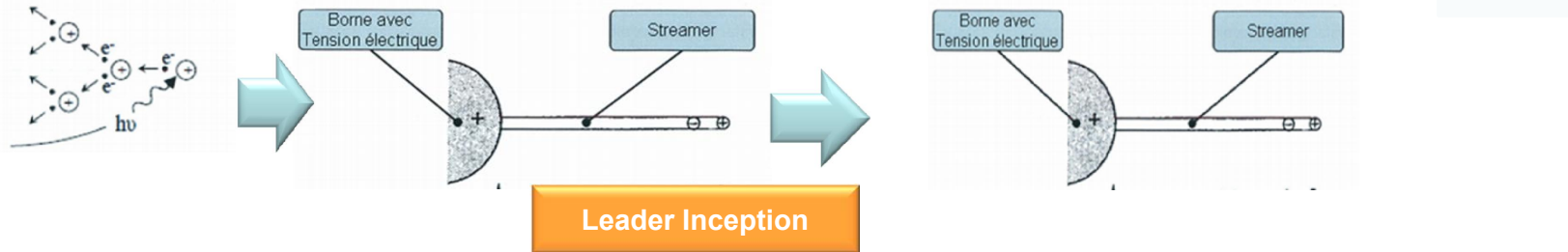
Validation intéressante

Proposition d'un découpage 3 bandes en Kmoyen pour le SF6 et d'une méthode de Nordborg planck pour calculer les moyennes



Semble intéressant mais pas testé sur suffisamment de conditions

Estimation des risques de reclaquage dans un HVCB au courant zéro



The tested devices:
 245kV at 50Hz and filled with SF6.
 18.9 kA (T30), TRV peak is 500kV with a rate of 13kV/μs.

$$\Delta U_C = \int_0^L E_{cr,f}(z) \cdot dz < \Delta U_0 = \int_0^L E_0(z) \cdot dz$$

Restrike criterion
 $U_c/U_0 < k$

Leader Propagation

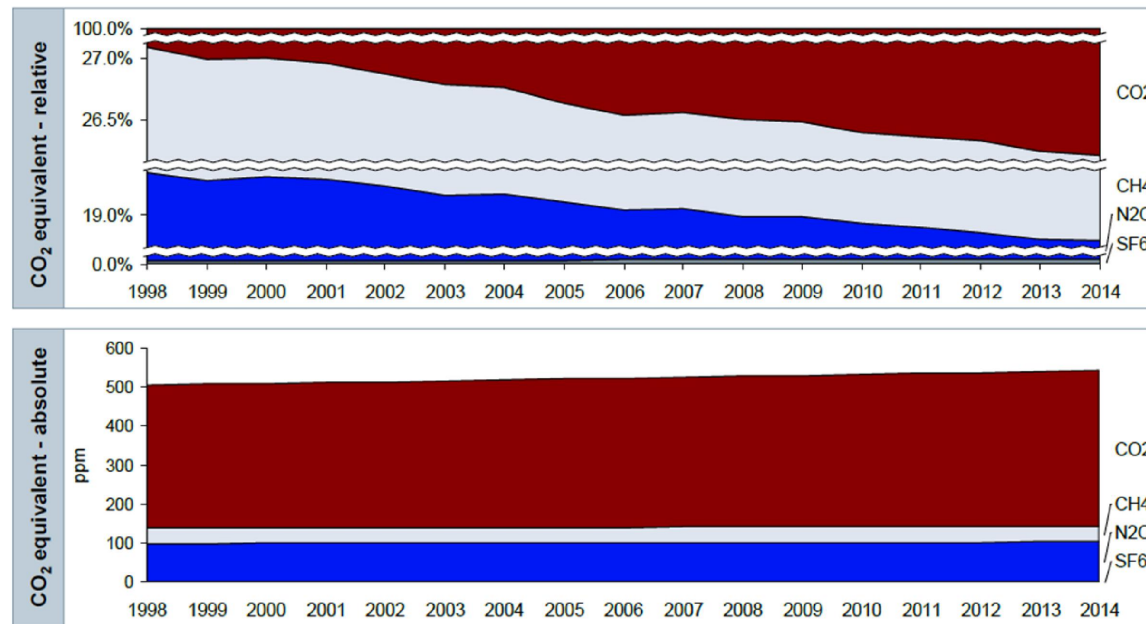
Bonne approche pour le claquage diélectrique



- L'auteur fait une étude de l'impact environnemental du SF6

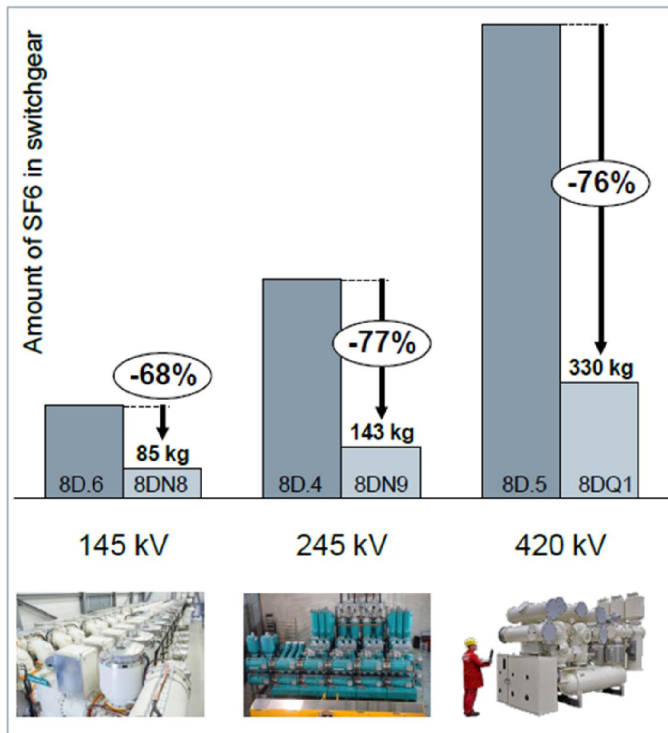
- Greenhouse gases in atmosphere
- History in electrical insulation and arcing in switchgear
- CO2 footprints of switchgear
- Requirements for SF6 alternatives

Distribution of CO₂ equivalents over the last 20 years



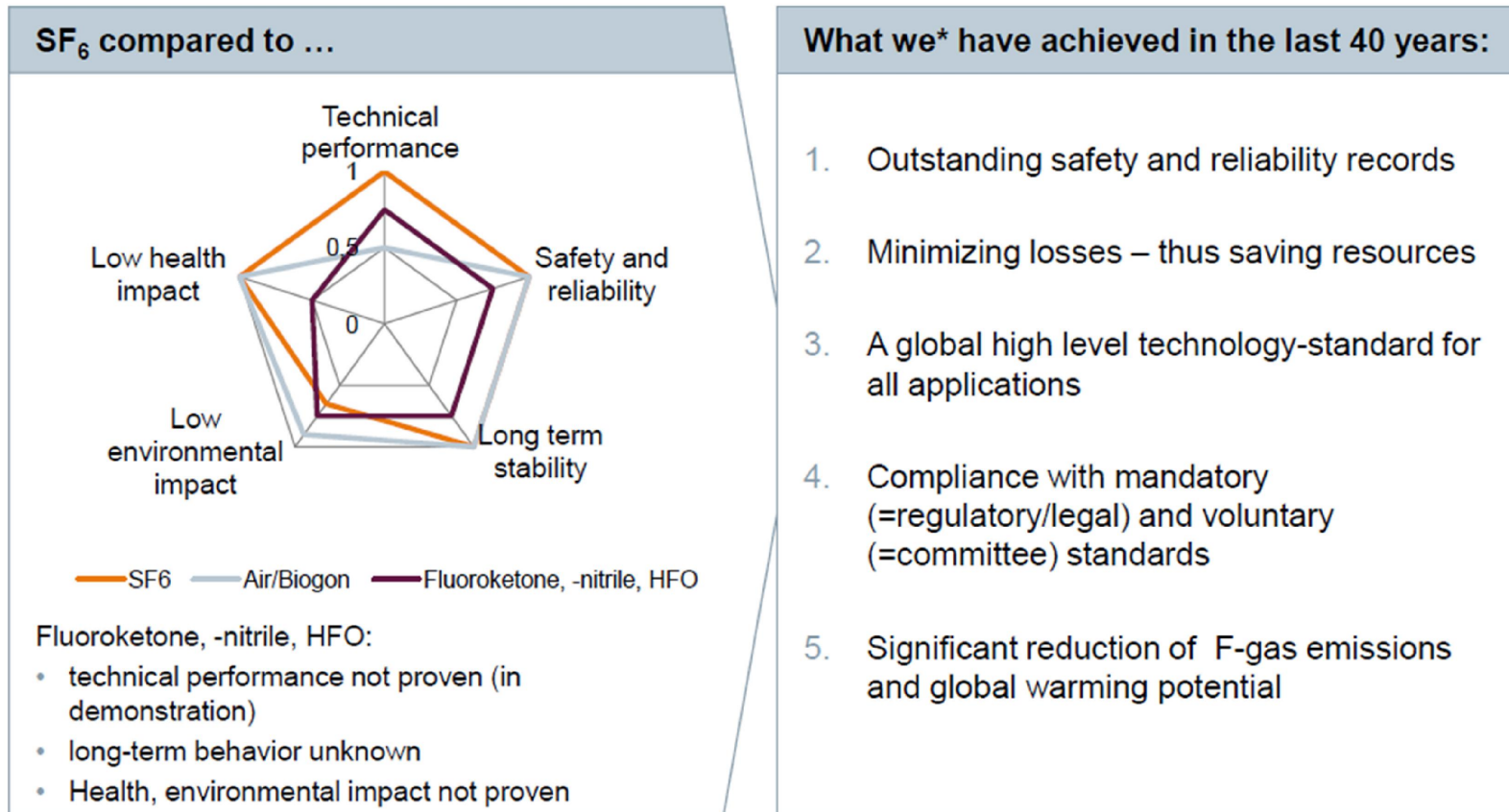
Le SF6 est « négligeable »

- CO2 footprints of switchgear



- New equipment uses significantly less Sulfur Hexafluoride - size, mixtures with Nitrogen
- Closed loop, recycling of Sulfur Hexafluoride
- Today's equipment ensures leakage rates
 high voltage: < 0.5%
 medium voltage: < 0.1%
- Further leakage reduction, e.g. during operation by leakage repair without undue delay
- Controlled pressures systems will be replaced by closed or sealed pressure systems (state-of-the-art for medium voltage switchgear: "sealed for life", ~40 yrs.)
- Phase out of old, leaking equipment

- Requirements for SF6 alternatives





SF6 Alternative Development for High Voltage Switchgears (P. Robin Jouan – Alstom)

Nouveau gaz G3



- Low Global Warming Potential: **better than 98%** reduction versus SF₆ (GWP = 380 CO₂ equiv. vs 23,500 for SF₆).
- Dielectric performance: **70% to 100% of SF₆ performance** depending on operating temperature and maximum pressure
- Operating temperature: **-25°C (GIS) and -30°C (AIS)** accessible
- Interrupting performance: **test duties performed on 145 kV prototype**
- Toxicity: **same toxicity classes as SF₆**, for both new and polluted gas.
 - MSDS available.
- Corrosion: **compatible with usual materials** of High Voltage equipment
- Flammability: **non flammable as SF₆**
- Chemically stable : **no degradation up to 600° C.**
- **EU Reach registration : done.** (Registration, Evaluation, Authorization and restriction of Chemicals)
- Gas handling cart and analysis : **under development.**



Thématique Applications

Conférences invitées

- Why the Arc, and its Interactions with the Electrodes, Are Important in predictive Modeling of Arc Welding - A.B. Murphy (AUS)
- Pulsed Plasma Spraying of Liquid Feedstock for Coating Elaboration (V. Rat (CH))
- Extended Methods of Emission Spectroscopy for the Analysis of Arc Dynamics and Arc Interaction with Walls (D. Uhrlandt (DE))
- Understanding the Mechanisms of Capillary Arc Discharge Plasma and the Interactions between plasma Jet and Propellants Used for Electrothermal-Chemical Launcher X. Li (China)
- The Problem of Chemically Active Plasma Nonequilibrium. Review V. Chernyak (UA)

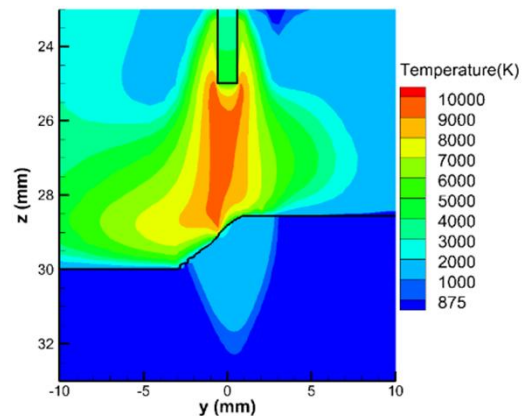
Lectures thématiques

- Preliminary Study of Mixing of Plasma Species in a Hybrid-Stabilized Argon-Water Electric Arc - J. Jeništa (CZ)
- Peculiarities of Interaction of Electric Arc Plasma and Composite Electrodes' Working Surface - A. Veklich (UA)
- Study of Nitrogen Atom Recombination by Optical Emission Spectroscopy - V. Mazánková (CZ)



Etude du soudage MIG basée sur un outil numérique très complet développé par le CSIRO

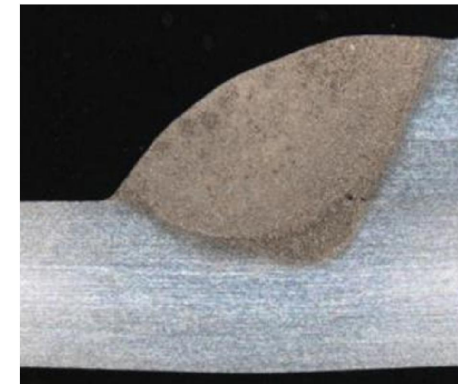
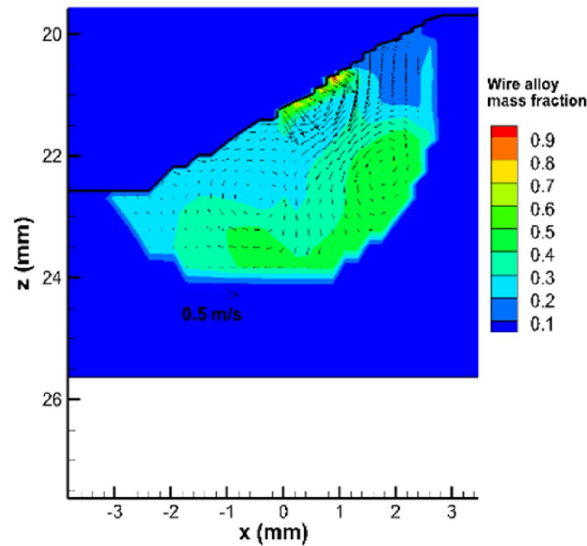
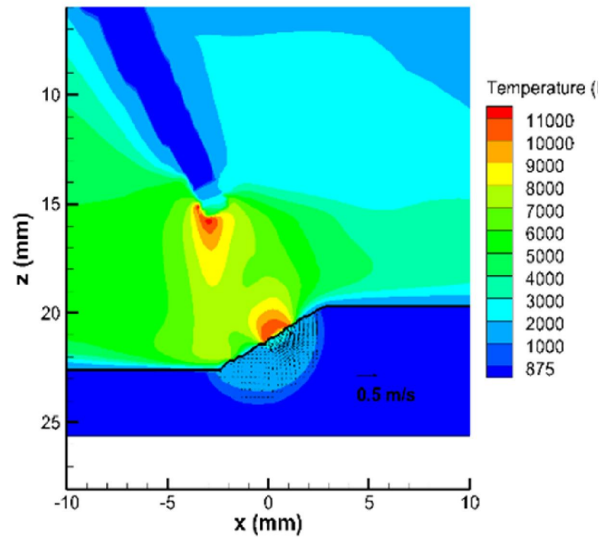
- Modèle fluide « maison » volumes finis
- Interaction couplée bain/plasma/vapeurs
- Prise en compte simplifiée de droplets (valeurs moyennes – psi cell)
- Prise en compte du mouvement de la torche
- Prise en compte déformation et stress mécanique (**novateur**)
-
- Validé dans de l'aluminium ce qui simplifie les données (Marangoni notamment)



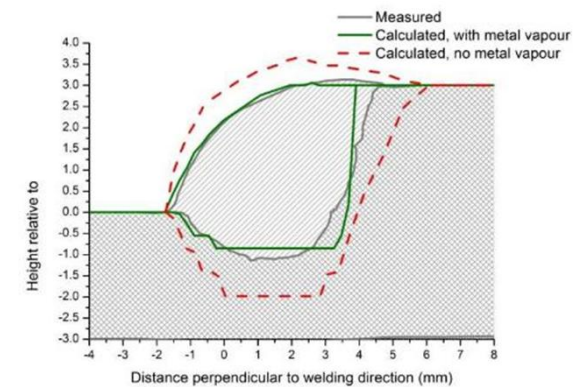
- Très bonnes comparaisons dans le cordon de soudure notamment)

$$I = 104 \text{ A}, V_W = -0.6 \text{ m/min}, V_{\text{feed}} = 4.7 \text{ m/min}$$

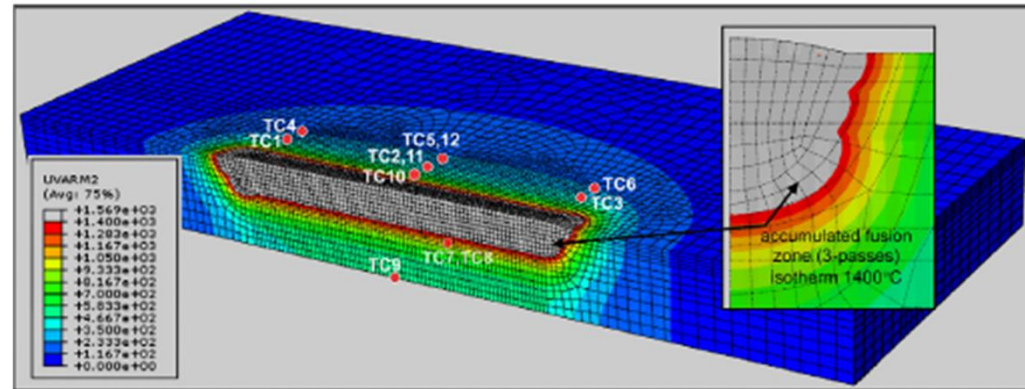
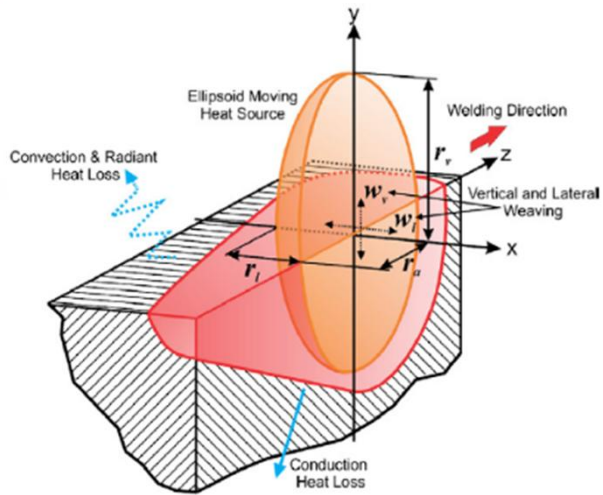
$$f_{\text{drop}} = 93 \text{ Hz}, \text{AA 5754}, 30^\circ \text{ work angle}$$



Important de prendre en compte les vapeurs de métal dans le plasma



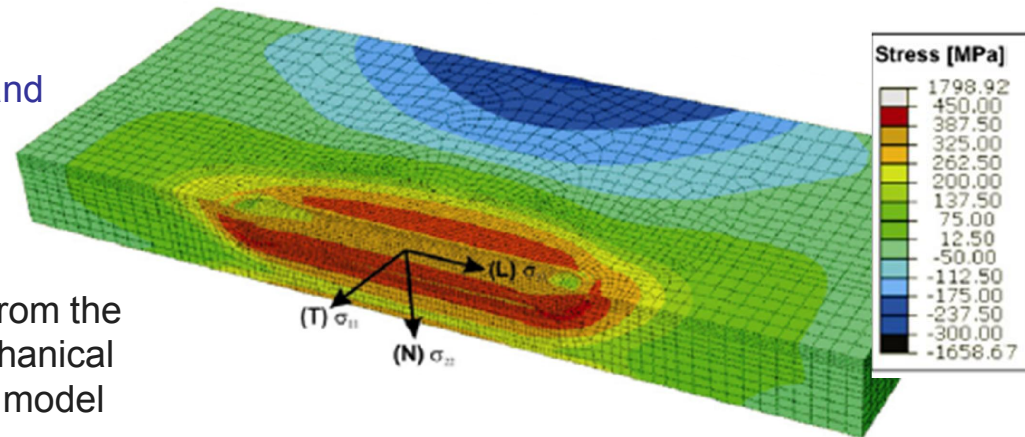
- Residual Stress & Deformation: Standard Approach



The free parameters are determined by fitting to thermocouple measurements

A heat source (3D or 2D) with free parameters is used to represent the arc and weld pool

Longitudinal (L) σ_{33}

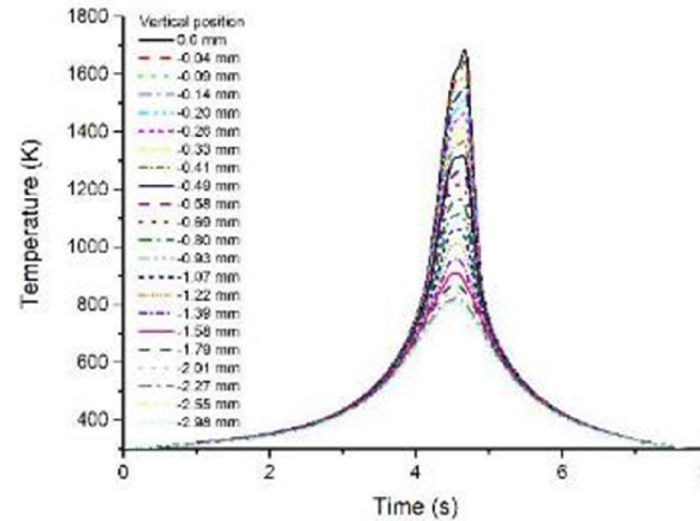
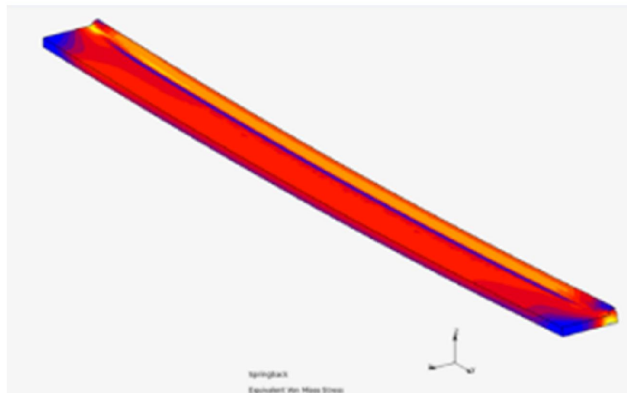


The residual stress is calculated from the thermal histories and thermomechanical properties using a finite-element model



- The Arc Model Predicts Thermal History, Weld Pool Surface Shape, Mixing of Droplets in Weld Pool

Run the arc welding model for the selected parameters to obtain the thermal history, surface shape and weld composition



Calculate the residual stress from this data and thermomechanical properties using a FE model



Outil pour les soudeurs

The image displays two screenshots of the ArcWeld software interface, illustrating the settings and simulation parameters for arc welding.

Left Screenshot (Settings):

- Project: Arc current (A) 95.00, Gas flow (cubic feet/hour) 30.00
- Solver: Wire feed rate (m/min) 4.32, Droplet frequency (1/s) 93.00
- Welding parameters: Welding speed (m/min) 0.90
- Welding parameters: Fillet geometry, Bead-on-plate geometry

Right Screenshot (Simulation status):

- Project: Z-thickness of lower sheet of workpiece cathode (mm) 3.00, Z-thickness of upper sheet of workpiece cathode (mm) 3.00
- Solver: Arc length (mm) 5.00, Diameter of wire anode (mm) 1.20
- Welding parameters: Work angle of wire anode (relative to horizontal) (degrees) 60.00, Travel angle of wire anode (relative to horizontal) (degrees) 90.00

The right screenshot also includes diagrams illustrating the work angle and travel angle relative to the horizontal.



Conclusions

- Most arc welding models consider only the workpiece
- However, two-way interactions between the arc and electrodes play a critical role:
 - The shape of the workpiece affects the heat transfer from the arc
 - Droplets transfer momentum, energy and different alloys to the weld pool
 - Metal vapour increases radiation from the arc, cooling the arc and weld pool
- Only by including the arc in the computational domain can these effects be considered
- Inclusion of the arc also allows important properties such as residual stress and distortion to be predicted without the need for calibration measurements

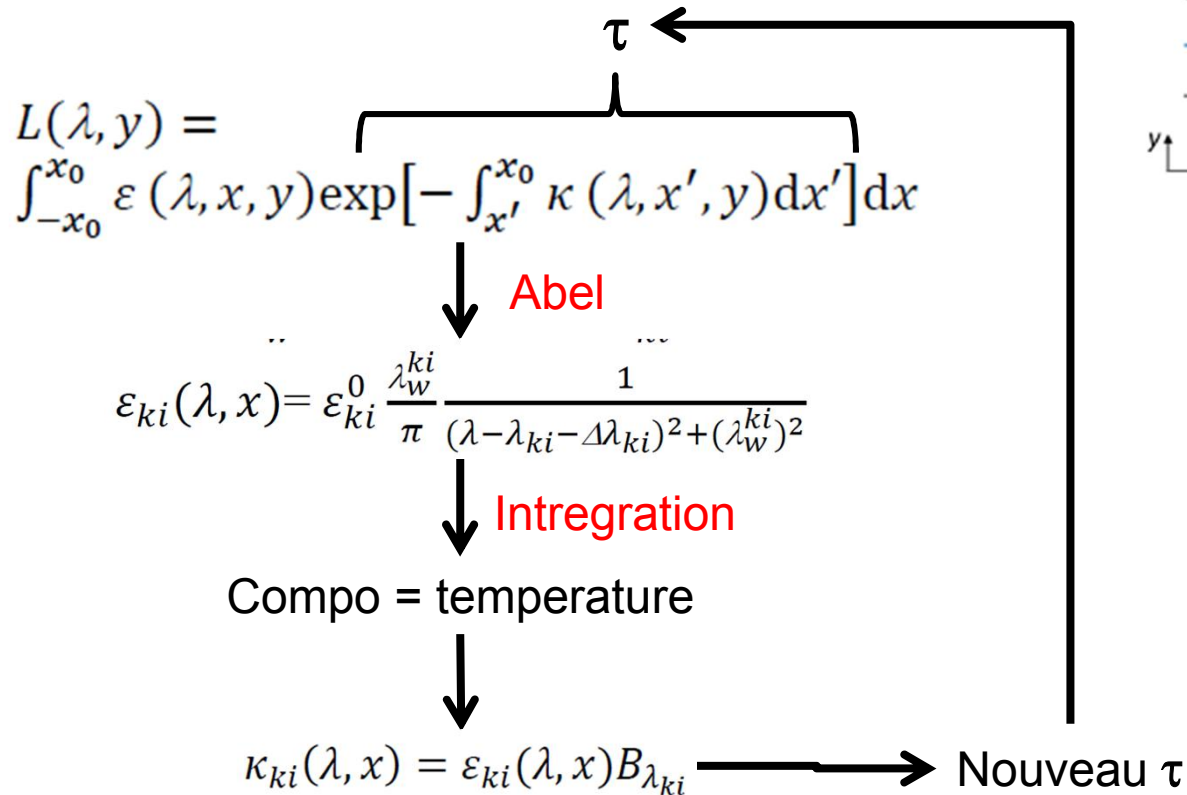
Revue de méthodes spectroscopiques d'émission « améliorée » Appliqué à des cas en présence de vapeurs métalliques

- **Méthodes améliorées en OES**
 - Simulation de spectres
 - Prise en compte de l'absorption dans l'inversion d'Abel
- **Application à un arc libre avec ablation de matériaux**
 - Ablation de cuivre
 - Ablation de céramique



- **Méthodes améliorées en OES**

- Prise en compte de l'absorption dans l'inversion d'Abel



- **Méthodes améliorées en OES**
 - Simulation de spectres avec notamment du cuivre

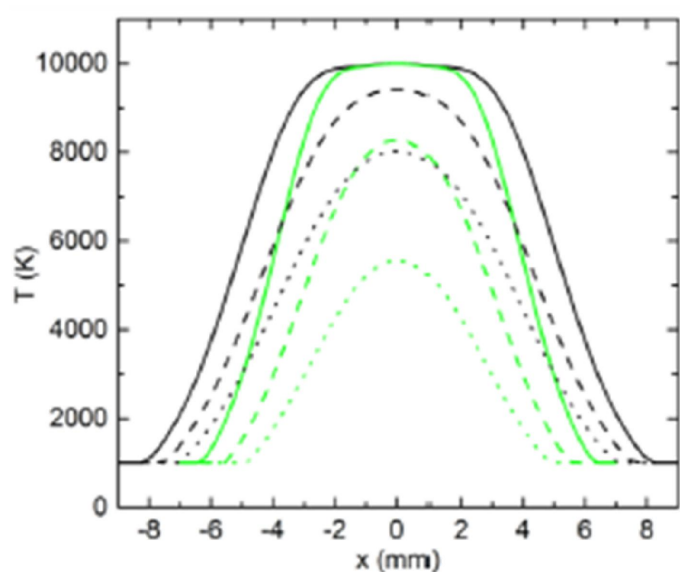


Fig. 2: Examples of considered radial arc temperature profiles (in green and black): temperature along the line of sight for the central side-on position (solid lines) and for side-on positions $y=3$ mm (dashed lines) and $y=4$ mm (dotted lines) from the arc axis.

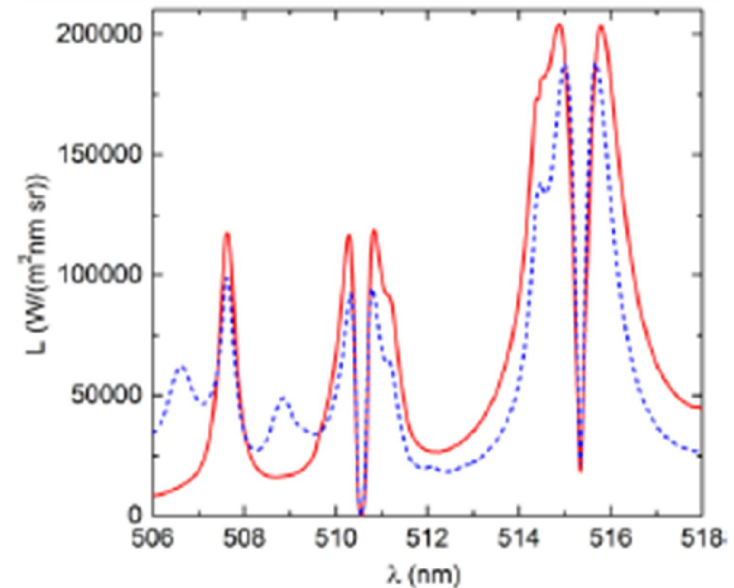


Fig. 3: Examples of radiance simulations for the radial temperature profile similar to the black curve in Fig. 1 but maximum temperatures 12 kK (red solid line) and 15 kK (blue dashed line) for the central side-on position.

- **Application à un arc libre avec ablation de matériaux**
 - Dans l'air avec electrode cuivre et ablation de matériaux céramique

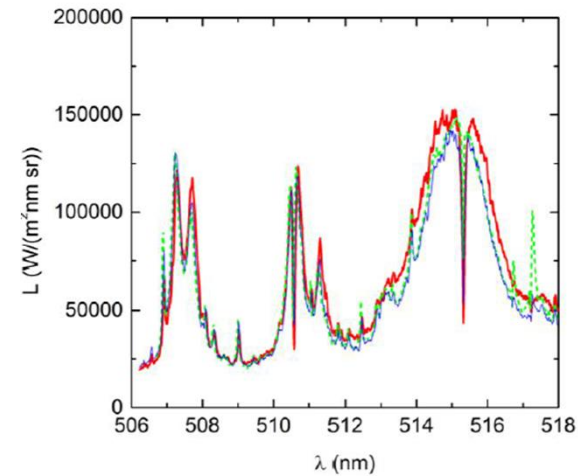
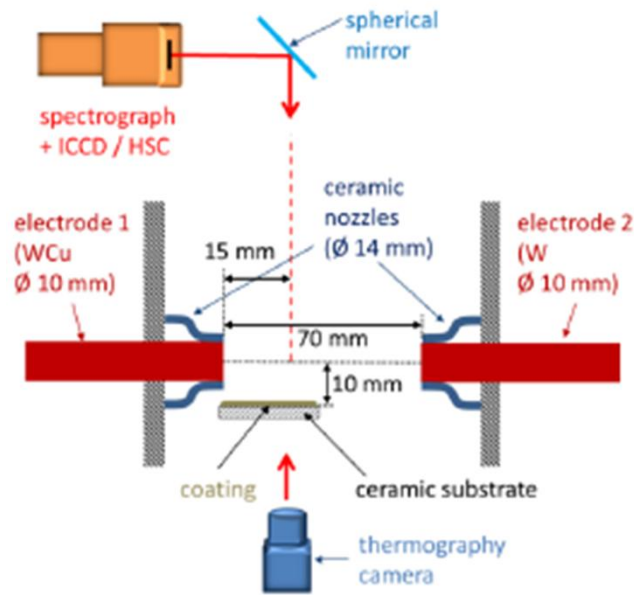
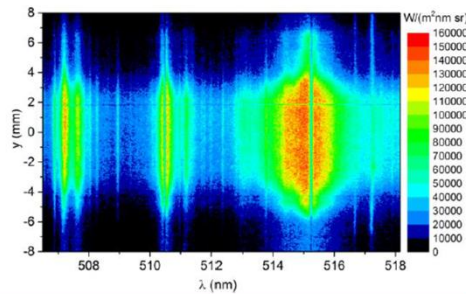


Fig. 11: Measured and calibrated spectral radiance L for $y=0$ for the cases of the substrate without coating (solid red line), with $MgCO_3$ + organic binder coating (thin solid blue line), and with $MgCO_3$ + plaster coating (dashed green line).



Obtention de températures



Thématique disjoncteur basse tension

Conférences invitées

- Low Voltage Arc Interruption Modeling Challenges (V. Narayan)

Lectures thématiques

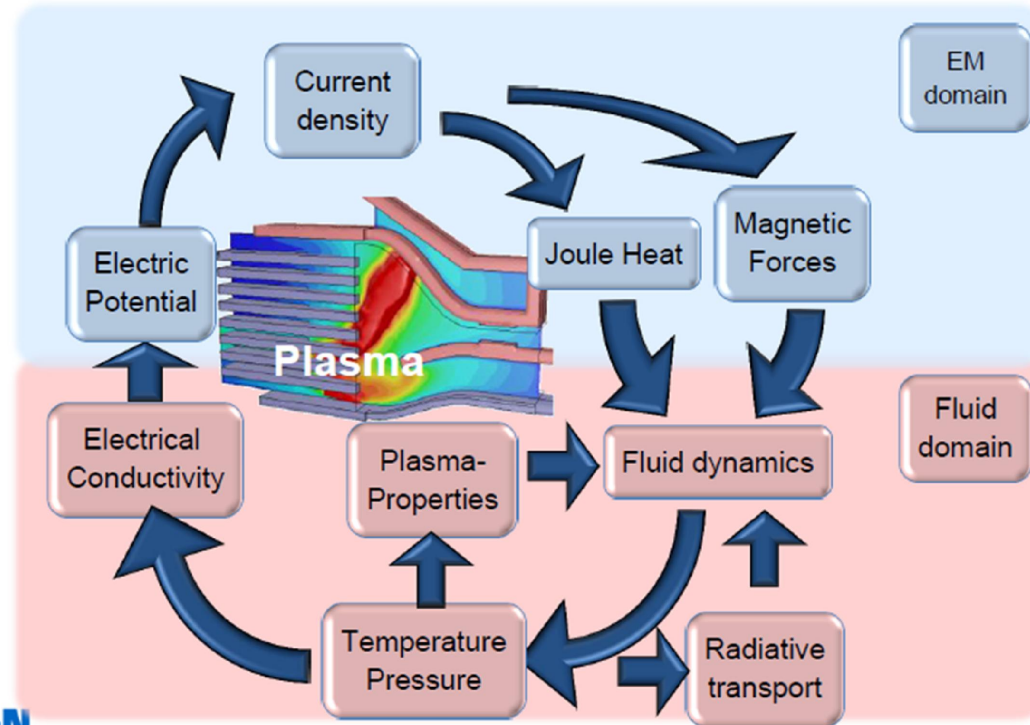
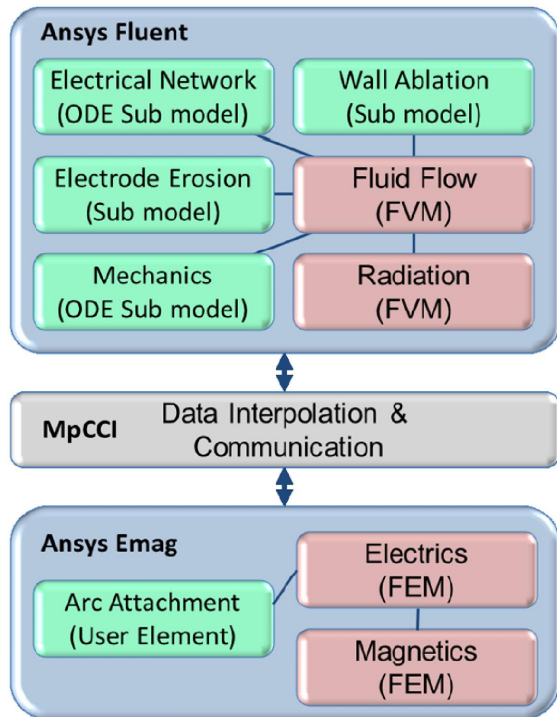
- Electrical Arc Movement in Low-Voltage Circuit Breaker - J. Quéméneur (Fr)
- Application of Laser Arc Imaging Technology to Observe Arc Behavior and Contact Motion - J. Qu (CH)
- Air Flow Measurement during Medium-Voltage Load Current Interruptions - N.S. Stoa-Aanensen NO

Posters

- Arc Simulation in Low Voltage Switching Devices, a Case Study - R. Bianchetti (CH)

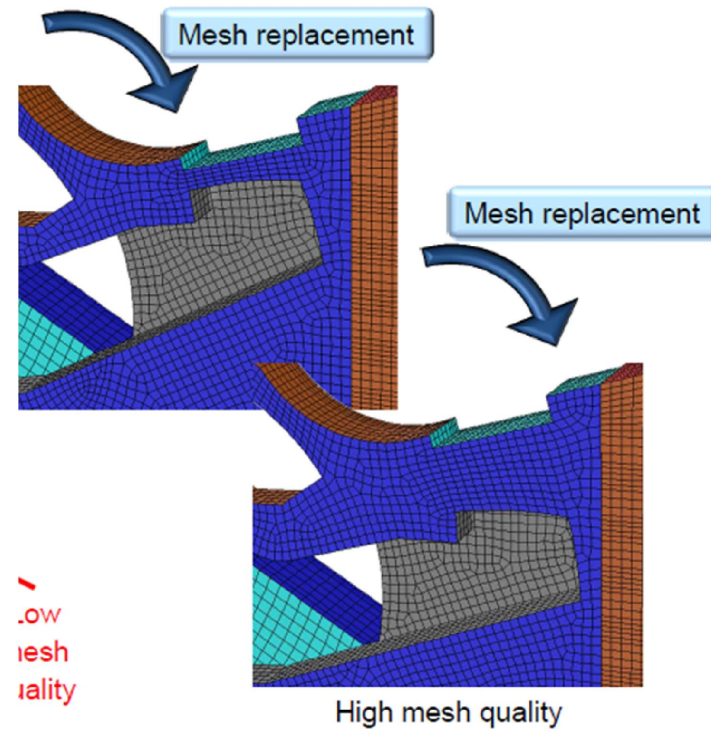
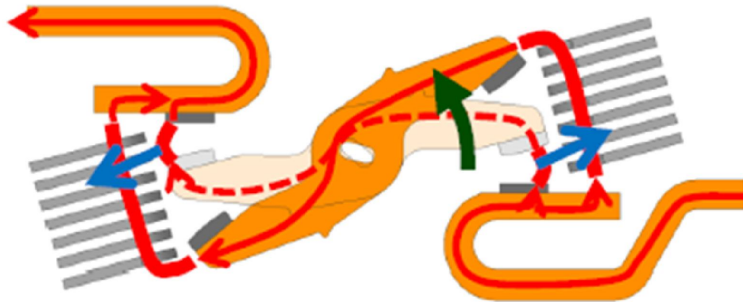
Modèles dans les LVCB

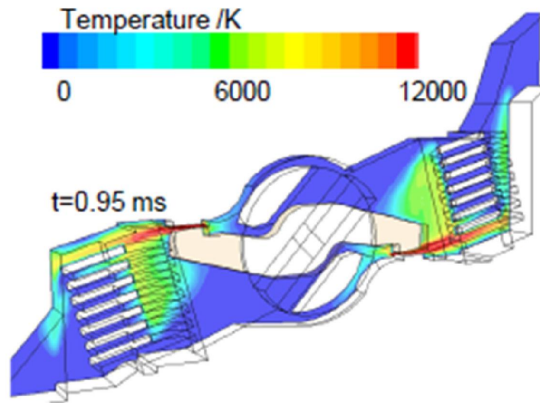
- Un challenge : Les contacts mobiles
- Le mouvement de l'arc (mais l'auteur donne peu de précisions)



Pour le mouvement des contacts un gros effort est nécessaire sur le maillage

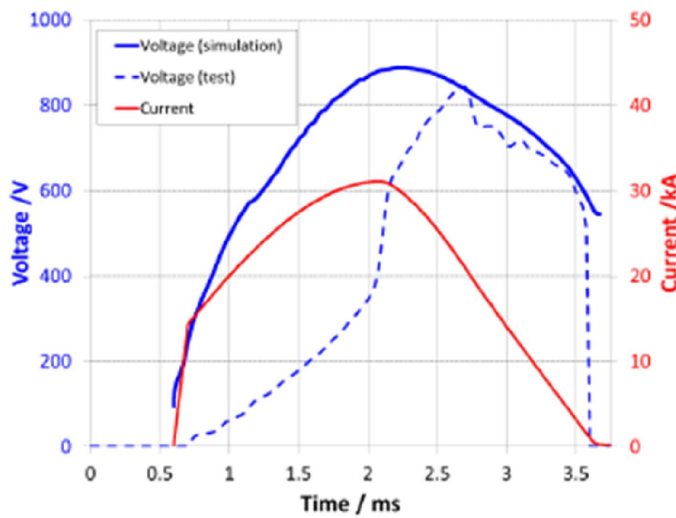
Molded case circuit breaker
MCCB



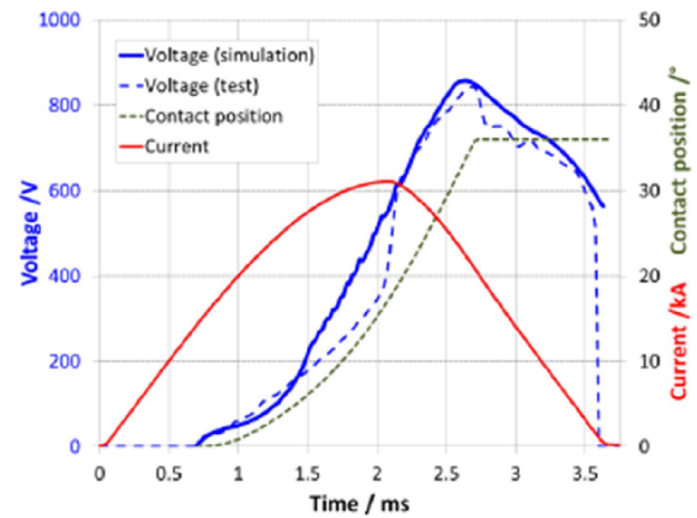


- 630A double break design
- 50 kA @ 440V AC interruption

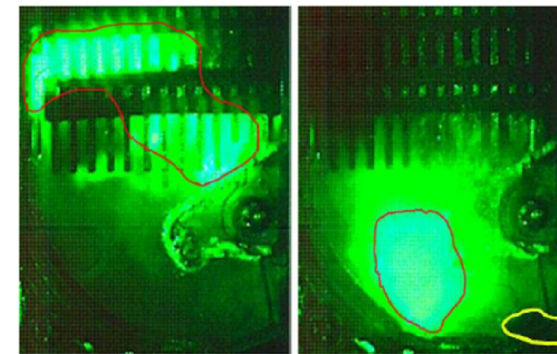
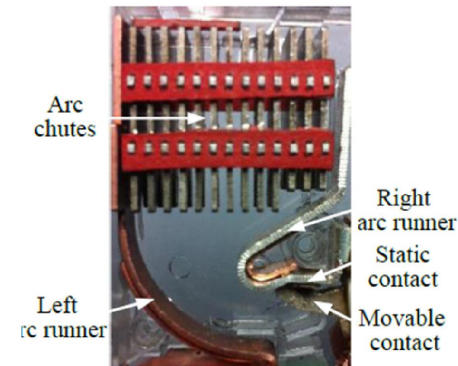
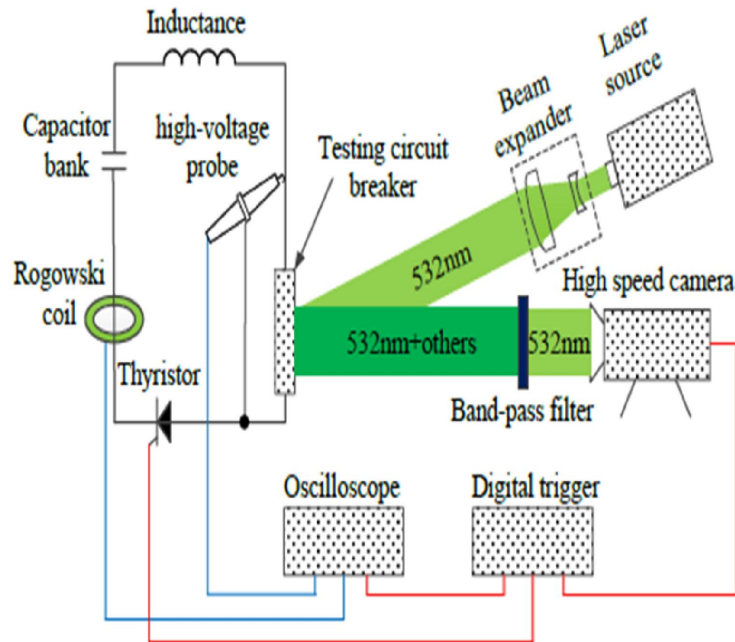
Without arm motion



Including arm motion



Observation d'un disjoncteur à l'aide d'un laser



(k) 4.83ms, $U_{arc}=308V$ (l) 5.83ms, $U_{arc}=58V$

Permet d'observer le mouvement des contacts et en particulier les rebonds et la vitesse de ces derniers en présence de l'arc

Pour finir.....

