

Rapport de D. Hong au nom du LOC

Partie 1 : des données sur la conférence

Partie 2 : articles sélectionnés dans les Topics B-M





20th International Conference on Gas Discharges and their Applications

6 au 11 juillet 2014 à Orléans

Une forte implication de l'AAE :

≻Organisateur GREMI, membre de l'AAE

Membre du comité « Executive Management Committee » : Alain

Membres du comité « International Scientific Committee » : Alain, Jean-Marc, Philippe et Dunpin

➢ Participation des membres : Alstom, Schneider, Onera, Laplace, Laept, Spcts et GREMI

Animation d'un workshop (table-ronde): Yann (WS1), Philippe (WS3 avec Seeger)
 Session chairs : Alain, Philippe, Pierre, Jean-François

Sponsoring : AAE (1250€TTC) et Alstom (1200€HT)







Nomber of attendees Vs countries (221 attendees for 29 countries)



Number of papers Vs Topic (in percentage, 175 proceedings)





Number of papers Vs country (1st author's institution, , 175 proceedings)





Number of papers Vs continent (1st author's institution, 175 proceedings)







Partie 2 Articles sélectionnés Topics B-M





Number of papers Vs Topic (in percentage, 175 proceedings)





Topic D: High Pressure Plasmas and Applications

D8: HIGH PRESSURE GAS DISCHARGE DEVICES APPLICATION FOR FUEL PROCESSING

V. Messerle, A. Ustimenko, O. Lavrichshev, E. Ossadchaya

Combustion problems Institute, Research Institute of Experimental and Theoretical Physics, Almaty, Kazakhstan

CONCLUSION

Traitement par plasma thermique de combustibles gazeux et solides.

Mots clés : Pyrolyse par plasma, gazéification, craquage d'hydrocarbures, etc.



The optimal ranges of recommended process parameters for plasmochemical processing of fuel

Fuel / plasma	T. K	Specific power consumption,	Fuel conversion	Concentration mg/Nm ³	
forming gas		kW·h/kg of fuel	rate, %	NO _x	SO _x
1	. Plasmoch	emical preparation	of coal for combu	stion (air)	
1.5–2.5	800-1200	0.05-0.40	15-30	1–10	1-2
	2. C	omplex processing	of coal (water stear	n)	
1.3–2.75	2200-3100	2–4	90–100	1–2	1
	3. P	lasma gasification (of coal (water stear	n)	
2.0-2.5 1600-2000 0.5-1.5 90-100 10-20 1-10					1–10
	4. Radiant-plasma processing of coal (air)				
1.5–2.5	800-1200	0.1-0.45	22–45	1–10	1-2
5. Pl	asma proc	essing of uranium-b	earing solid fuels	water stear	n)
8-12	2500-3150	2–4	55-70	1-3	1-2
6. Plasmochemical hydrogenation of coal (hydrogen)					
10	2800-3200	6.5–8	70–100	0	0
	7. Plasmochemical cracking of a propane-butane mixture				
18 м ³ /ч	1500-2500	2.2–3.8	98-100	0	0

D9 : HIGH PRESSURE PLASMA TORCH

V.E. Messerle, A.B. Ustimenko, V.Zh. Ushanov



2014

Anode and cathode parts of the 100 kW plasma torch



 \checkmark Long-life DC arc plasmatron up to 200 kW of adjustable power was developed and tested in laboratory and industrial conditions.

Life length of the cathode totals more than 900 hours
 (normalement, durée de vie <500h). The experiments confirmed principal possibility for unlimited long-life of the cathode filmed
 with carbon nanostructural material (grâce à la présence du gaz d'hydrocarbures).

✓ On the base of atomic microscopy, SEM, TEM and the Ramanspectroscopy investigation, it can be concluded that the cathode condensate is a composite carbonic stuff made of carbon nanoclusters which consists mainly of <u>single and multi-walled carbon</u> <u>nanotubes</u> and other carbonic forms including some quantity of the copper atoms intercalated to the carbonic matrix.

✓ In the regimes with overflow of propane/butane the soot contained 10 % of composite material in the form of nanotubes was received.

gd²⁰¹⁴

D10 : Influence of Arc Energy Absorbers on the Enclosure Effect in Case of Internal Arcing in Electrical Installations

S. WETZELER¹*, K. ANANTAVANICH² AND G. J. PIETSCH¹

 ¹ Institute for High Voltage Technology, RWTH Aachen University, 52056 Aachen, Germany
 ² Transmission System Engineering Division, Electricity Generating Authority of Thailand, Nonthaburi 11130, Thailand



- Arc energy absorbers are a means to reduce overpressure due to internal arcing in relief rooms by heat absorption.
- Absorbers reduce the effective size of the relief opening with the result of enhanced thermal energy input in the arc volume.
 By this the heat absorption effect in the relief room is less pronounced or even overcompensated due to the enclosure effect.
 - → A proper choice of the effective absorber size is necessary.
 This can be realized by either enlarging the relief opening or enlarging the size of the absorber (in a distance of the opening).

gd²⁰¹⁴

D11: Influence of Insulating Gas on Pressure Rise in Electrical Installations due to Internal Arcs

S. WETZELER¹, Y. CRESSAULT², <u>G. J. PIETSCH¹</u>*

¹ Institute for High Voltage Technology, RWTH Aachen University, 52056, Aachen, Germany
 ² Laplace, Université de Toulouse 3, 31062 Toulouse, France



•Replacing SF₆ by CO₂ the switchgear design has to be re-considered with respect to internal arcing

 Especially the pressure rise within the switchgear compartment: overpressure lowest in SF₆ and highest in air → CO₂ in between



•For reliable pressure calculations in CO₂ insulated switchgear the input data are provided

- Pressure and temperature dependent gas data of CO₂/air mixtures
- Thermal transfer coefficient
- Arc voltage



Development of a **3D** model of **coupling arc and material** in a TIG configuration taking into account the **movements** in the melted zone and the **presence of metallic vapours**

2014

GD - July 9th 2014

This code is applied for **arc blow deflection** due to mass clip position

Influence of **process parameters** on blow deflection Investigate other kind of magnetic deflection

Include the torch movement and the cathode into the model



Modeling Nozzle Geometry changes Due to the Ablation in High-Voltage Circuit Breakers

Sina Arabi[†], Jean-Yves Trépanier[†], Ricardo Camarero[†] and Assen Vassilev[‡]

[†]Ecole Polytechnique de Montreal and [‡]ALSTOM Grid, ARC

To presents a new mathematical model to couple plasma flow simulation with erosion and movement of the PTFE walls in a HV circuit breaker chamber



- A transient model was used to study the erosion of a PTFE nozzle in a circuit breaker in a long-operation time,
- The presented model includes all the relevant physics of the arcing flow
- The two regions, gas and PTFE, are coupled at the surface by appropriate energy and mass balances
- The radiated heat from the arc recessed the nozzle surface, widened the throat and consequently, raised the mass flux
- Sising the nozzle mass flux, affects the performance of the whole system
- This study has demonstrated its ability to simulate qualitatively and to some degree, quantitatively the ablation effect under operating conditions

High Pressure Plasmas and Applications



PLASMA-AIDED GASIFICATION OF BIOMASS STUDY OF A SELF-BLOWING GLIDARC

P. ESCOT BOCANEGRA*, J-M.CORMIER,

GREMI, PolyTech'Orléans, 14 rue d'Issoudun, BP 6744, 45067 Orléans Cedex 02, France

ABSTRACT

This paper talks about the plasma effect on different mixtures of oxygen and propane in a gas recirculation plasma reactor. In addition numerical results obtained from PFR simulation are used for discussion.. The plasma used in the reactor is made by three gliding atmospheric pressure arc discharges supplied independently by three direct current generators. The results show that the mixture composition influences the consumption of C_3H_8 and O_2 and the production of NO_x , CO and CO₂.



Fig. 1 Self blowing glidarc



Fig. 2 Three gliding arc in plasma reactor



13: Study of a high current arc used for direct lightning effect characterization

C. Zaepffel, R. Sousa Martins, L. Chemartin and Ph. Lalande

ONERA, Lightning and plasmas applications unit

- Designed of a test stand able to produced DBC* current waveform with 100 kA peak current
- Use of OES to evaluate T and P (LTE)
- Use of stereo correlation to measure mechanical deformation



Future works:

- Results on composite material (already successfully tested)
- Tomography to ascertain cylindrical assumption
- Database improvement (metallic species) and validation
- Coupling fast camera with the spectrometer
- Schlieren
- Another test stand delivering current A waveform (200 kA and more...)



J3: Electric spark discharge in air characterization using electrodes erosion

S.Bernard, P.Gillard (PRISME, univ of Orléans) <u>S.Pellerin</u>, M.Wartel, M.Sankhe, D.G.Astanei (GREMI)

- Context : dust explosion hazards
- Experimental device: modified Hartmann tube (generation of a dust cloud)
- Ignition parameters determinations
 - Minimum Energy of Ignition
 - Ignition delay
- Optical Emission Spectroscopic diagnostic
 - Used methods
 - First integrated results
- Summary and Conclusion
 - N_e and T determinations
 - Spatially and temporally resolved diagnostics



- First diagnostic of the Spark, using eroded material
 - Spark (*diagramme de Boltzmann, OH-Specair*)
 - Plasma that seems close to the equilibrium
 - Solve Cooling effect of the metallic vapours close to the cathode

Next steps

•

- Determination on electron density, and plasma composition
- Determination of the spatial temperature and electron density distributions, at least close to the cathode
- Study of the temporal evolution of the plasma, and interaction with the dusts



J6: INVESTIGATIONS ON THE INTERACTION BETWEEN SWITCHING ARC AND QUENCHING GAS IN INSULATING NOZZLES BY OPTICAL MEASUREMENTS

Gregor Nikolic, Artur Mühlbeier, Dr. Patrick Stoller (ABB), Armin Schnettler

Institute for High Voltage Technology, RWTH Aachen University, 52056 Aachen, Germany





Optical Investigation Methods

Background Oriented Schlieren (BOS)

- Simplified arrangement, only camera and patterned background
- Determination of the deflection angle from the shift of the background pattern between reference recording without test object and recording with test object

$$\mathcal{E} = \frac{\Delta \cdot Z_B}{Z_D \cdot f} = \frac{\Delta'}{Z_D} \sim grad(n) \quad \text{(f = focal length)}$$

- Camera focuses on the background pattern
- Reconstruction of the refractive index field by filtered back projection





Experimental Setup

Circuit Breaker Model and Parameters

- Experiments in a synthetic test circuit with I_{peak} = 3.5 kA at f = 50 Hz
- Blow gas pressure of Δp = 0.7 MPa in the mixing volume
- Optical measurements using a PCO SensiCam 370 LF
- Exposure time t_{exp} = 200 ns
- Light source NANOLITE spark lamp with nanosecond flash duration
- Rotating blind shutter for reducing the light intensity from the arc during the high current phase





Summary and Outlook

- BOS method applicable for density measurements from one and two viewing directions
- Identification of a characteristic upstream shift of the Mach disc before current zero
- Identification of turbulent mixing at the boundary layer between arc plasma and blow gas flow
- Improved localization of the decaying plasma channel by measurements from two viewing directions

Next steps:

/**5**

- Expanding of the experimental setup to more than two viewing directions
- Increase of the image resolution



L4: Synthesis of (B-C-N) Nanomaterials by arc discharge

D .Gourari, M. Razafinimanana, M. Monthioux, R.Arenal, <u>F. Valensi</u>, S. Joulié, V. Serin

Boron-Carbon-Nitrogen $(B_xC_yN_z)$ nanotubes have potential applications such as photo-luminescent materials, electron emission, or high temperature transistors



1- Feasibility of the insertion of Boron in a graphenic structure (sp2) hybridization; a high content of B in the system is detrimental to the SWCNTs yield.

2- Identification and **correlation** of the **plasma properties**, **growth zone temperature** and synthesised nano-product.

3- Doping confirmation; synthesis of BN nanoparticles.

4- Further works are expected (temperature of the heavy particles determined by molecular spectroscopy, densities of species) to evaluate the role of the deviation from LTE (Local Thermodynamic Equilibrium) in the plasma on the synthesis and doping nanotubes.

M5: Electron temperature and density measurements in GTAW and GMAW processes by Thomson scattering

Marina Kühn-Kauffeldt, José-Luis Marquès and Jochen Schein

UniBw München, LPT, Neubiberg, Germany

Open question:

How the presence of different gases and metal vapor influences the behavior of the arc?

Useful tool:

Thomson Scattering as a diagnostic for the temperature and density of the welding arc plasmas

Advantages:

- simultaneous electron temperature and density measurement
- localized measurement
- knowledge of plasma composition is not necessary
- plasma has to be optically thin only in a small spectral range



- GTAW at I=150 A: maximum $T_e \approx 18000 K$ and $n_e \approx 1.4 e 10^{23} m^{-3}$
- GMAW at I=400 A: maximum $T_e \cong 14000 K$ and $n_e \cong 1.6 e 10^{23} m^{-3}$
- lower temperatures and higher densities in the GMAW process may result from presence of metal vapor in the arc



- Thomson scattering was successfully applied to stationary and transient welding processes
- data can be used to estimate plasma composition
- planned: validation of the GMAW measurement using Stark broadening for electron density measurement



20th international conference on gas discharges and their applications

MODELING NOZZLE GEOMETRY CHANGES DUE TO THE ABLATION IN HIGH-VOLTAGE CIRCUIT BREAKERS S. ARABI1*, J-Y. TRÉPANIER1, R. CAMARERO1 AND A. VASSILEV2 (p479)

1 Department of Mechanical Engineering, École Polytechnique de Montréal, Campus de l'Université de Montréal, H3T 1J4, Montréal, Canada

2 Alstom Grid, 130 rue Léon Blum, 69611 Villeurbanne Cedex, France

This paper presents a new CFD tool for transient analysis of surface ablation of a Poly-Tetra-Fluro-Ethylene (PTFE) nozzle of a high voltage circuit breaker.

Paper

review

The developed solver fully couples the arcing flow field inside a circuit breaker chamber including radiation, ablation and nozzle wall recession.

The presented numerical simulation evaluates the changes in the nozzle mass flux due to the recession of the PTFE surface, in 10 consecutive applied current cycles.



$$S_m = \frac{1}{V_p} \sum_{k=1}^{N_{sides}} \dot{m}_{p,k}, \qquad S_e = S_{ohm} + S_{rad} + e_g S_m,$$

Debitm² = frac Flux /(Hv + Eint3500 – Eint1000)

The radiative energy is computed from the P1 approximation as follow



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Solution Orléans

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The applied current cycle is repeated in **10 consecutive** times to predict the changes in the nozzle mass flux in a long-operation time. In the present simulation, the peak current is **56kA** and the arcing time for each cycle **is 6.4ms**.



Paper

review











Fig. 12: Geometry change after applying 10 current cycle.

By comparing the amounts between the end of the 10*th* and 1*st* cycles, there is about a 9.5% rise in the mass flow rate Real CB validation at ARC

ALS

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Paper review



July 6-11, 2014 - Orléans - France

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CFD BASED MULTI-PHYSICS SIMULATION OF COMPRESSIBLE FLOW THROUGH NOZZLE OF SF6 GAS CIRCUIT BREAKER

SUMEDH P. PAWAR¹* AND ATUL SHARMA²

¹ Global R&D Center, Crompton Greaves Ltd. and Ph.D. student, IIT Bombay, Mumbai, 400042, India

² Mechanical Engg. dept. IIT Bombay, Mumbai, 400042, India

The study is done on a simplified geometry - a convergent-divergent nozzle geometry with two electrodes called as **Lewis nozzle (EPM case)**

Numerical simulations are done using general purpose commercial CFD software ANSYS FLUENT 13.0. However, in-house C programs are developed to model physics such as MHD and radiation.

The numerical development and its coupling with th software is validated on a transient and 2-D axisymmetric problem - for a low DC current of 300.

A detailed CFD analysis is presented here to discuss the reasons for the variation of temperature, arc radius and arc voltage along the axis.



Fig. 4: (a-c) Temperature contour and Current density vectors (colored by radial Lorentz forces)-near the Cathode for (a,d) flat, (h,e) hemi-spherical and (c,f) elliptical tip of the electrodes





Fig. 7: Comparison of arc voltage for the various shapes of the tip of the electrodes.





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IMPROVED MODELING OF ABLATION PROCESS IN HIGHVOLTAGE CIRCUIT BREAKERS FOR SWITCHING ARC SIMULATION (A22 p155)

A. PETCHANKA¹*, F. REICHERT¹, J.-J. GONZALEZ² AND P. FRETON² ¹Siemens AG, E T HP CB R&D ENG 1, Nonnendammallee 104, 13629, Berlin, Germany ²Université de Toulouse, LAPLACE, 118 route de Narbonne, CNRS-UPS, 31062, Toulouse, France

utilization of an improved model for the ablation process in the simulation of on-load switching-off processes in high-voltage circuit breakers (HVCBs).

In order to describe the plasma arc behaviour, a transient axisymmetric model is used which is based on the Fluent software.

Paper

review



two species SF6-C2F4 gas mixture is considered Classical CFD from FLUENT

$$\nabla^2 \vec{A} - \frac{1}{c^2} \frac{\partial^2 \vec{A}}{\partial t^2} = -\mu_0 \vec{J},$$

$$Q_{rad} = \dot{M} \left(h(T) - h(T_p) + H_{vap} + \frac{v^2}{2} \right)$$

where Q_{rad} is the radiation flux, h(T) is the specific enthalpy of the ablated material and T_p is the pyrolysis temperature.

The PTFE walls are considered as non-detormable.





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Two cases of evaluation of evaporation enthalpy are considered: constant value $H_{vap} = 12 \text{ MJ/kg}$ [4] and pressure dependent $H_{vap} = H_{vap}(P)$.

Paper

review

The calculation of $H_{vap} = H_{vap}(P)$ is based on the Maximum Entropy Principle (MEP)



It is shown that the consideration of PTFE evaporation enthalpy in dependence on pressure yields to best agreement between experiment and simulation.

Nevertheless, the approximation of the constant enthalpy stays in a satisfactory agreement with the measurements at the interruption current 25 kA.





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RADIATIVE PROPERTIES OF SF6-C2F4-Cu MIXTURES IN HIGH VOLTAGE CIRCUIT BREAKERS ARC PLASMAS: NET EMISSION COEFFICIENT AND MIXING RULES (p229)

L. HERMETTE1,2, Y. CRESSAULT1*, A. GLEIZES1 , C. JAN1,2 and K. BOUSOLTANE2 1Université de Toulouse; UPS, INPT, CNRS; LAPLACE (Laboratoire Plasma et Conversion d'Energie), 2SIEMENS T&D E T HP GS R&D D G R1, 1 rue de la Neva, BP 178 38004 Grenoble, France

ABSTRACT

Paper

review

In this paper, we tried to estimate the radiative properties of SF6-C2F4-Cu thermal plasmas existing in High Voltage Circuit Breakers. The calculation was realized assuming LTE, binary and ternary mixtures with mass concentrations, temperatures from 300K to 30 000K and pressures of 1 bar and 8 bar.

Two methods were used to estimate these properties:

- the Net Emission Coefficient by neglecting the lines overlapping
- the mixing rules using either the NECs of the pure gases or the NECs of a given SF6-C2F4 mixture and of pure Cu plasma.







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Proposition of two mixture laws. The first one, called "ternary", tries to estimate the NEC of a ternary mixture from the NECs of the pure Gases

Paper

review

The second one, called "binary", is based on the NEC of the 50%SF6-50%C2F4 mixture and the NEC of the pure copper plasma







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lines' overlapping could lead to significant differences for the high pressures.

"binary" interpolation with molar proportions is the best mixing rule to quickly estimate the NEC of a ternary mixture.

This law must be tested at higher pressures, higher temperatures, and higher sizes of plasma.

Paper

review

New sophisticated laws have to be developed and tested in the future.







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CO2 ARC BEHAVIOR DURING CURRENT INTERRUPTION PROCESS IN A GAS CIRCUIT BREAKER WITH EXTERNALLY APPLIED MAGNETIC FIELD (p111)

T. TAKEMATSU1*, S. HIRAYAMA1, T. FUJINO1, M. ISHIKAWA1

S. OGAWA2, AND T. MORI2

Paper

review

1 University of Tsukuba, Tsukuba, 305-8573, Japan, takematsu@fmm.kz.tsukuba.ac.jp

2 Toshiba Corporation, Kawasaki, 210-0862, Japan

3D and time dependent MHD numerical simulations of a gas circuit breaker model with externally applied magnetic field for CO2 or SF6 gas (8kA max)

Numerical results show that applying **the magnetic field induces swirl flow**, which leads to the **pressure rise in the puffer chamber for both gases**. Just before second current zero, the arc forms cylindrical shape under the magnetic field for CO2 gas unlike SF6 gas where the arc column forms spiral shape.

Arc conductance is reduced by applying the magnetic field for both gases because heat convection around the arc is enhanced. Thermal interruption capability can be improved by applying the magnetic field for both gases.

No explanaition for the differences of behaviour



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Fig. 5 Three-dimensional distributions of vector of Lorentz force and isosurface of temperature T = 5000 K with applied magnetic field at (a) t = 15.0 ms and (b) t = 20.0 ms for CO₂.

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NUMERICAL SIMULATION ON TWO-TEMPERATURE CHEMICALLY NON-EQUILIBRIUM STATES IN DECAYING SF₆ ARCS AFTER APPLICATION OF RECOVERY VOLTAGE

Y TANAKA¹, K SUZUKI²

¹Faculty of Electrical and & Computer Eng., Kanazawa Univ., JAPAN.

ABSTRACT

This paper describes calculation results by the developed two-temperature (2T) chemically non-equilibrium (CNE) model for a decaying SF₆ arc plasma with transient recovery voltage (TRV) application. The developed model solves energy equations for electrons and heavy particles, mass conservation equations for each of 19 species in SF₆ arc plasmas, accounting for totally 122 reactions. Transient distributions of electron temperature and heavy particle temperature as well as CNE composition were obtained for a decaying SF₆ arc plasma considering non-equilibrium effects. Energy for electrons:

$$\frac{3}{2}kn_e \frac{DT_e}{Dt} = \nabla \cdot (\lambda_{tr}^e \nabla T_e) - Q_{e-h} + Q_{heat}^e$$
(6)

$$Q_{\text{heat}}^e = \nabla \cdot \left(\frac{1}{m_e} \frac{5}{2} k T_e \Gamma_e\right) + \sum_{\ell=1}^{L} \sum_{(\beta_{e\ell}^\ell, \beta_{e\ell}^\ell \neq 0)} \Delta Q_\ell$$

$$+\sigma_{\rm e}|E|^2 - P_{\rm rad} - Q_{\rm exc}^e$$

Mass of species j:

$$\rho \frac{DY_j}{Dt} = \nabla \cdot (\rho D_j \nabla Y_j) + S_j, \qquad (8)$$

$$S_{j} = m_{j} \sum_{\ell}^{L} (\beta_{j\ell}^{t} - \beta_{j\ell}^{t}) \left(k_{\ell}^{t} \prod_{i=1}^{N} n_{i}^{\beta_{i\ell}^{t}} - k_{\ell}^{t} \prod_{i=1}^{N} n_{i}^{\beta_{i\ell}^{t}} \right) (9)$$

The equation of state:

$$p = p_e + p_h$$
 (10)

$$p_{e} = n_{e}kT_{e}$$
 (11)

$$p_{\rm h} = \sum_{j(j\neq e)}^{N} n_j k T_{\rm h}$$

Mass density:

(7)

(12)

$$\rho = \frac{p}{k\frac{Y_{\rm c}}{m_{\rm c}} + k\sum_{j=1(j\neq {\rm e})}^{N} \frac{Y_{j}}{m_{\rm j}} T_{\rm h}}$$
(13)

Energy conversion by excitation:

$$Q_{\text{exc}}^{e} = \sum_{j=1(j\neq e)}^{N} \left[k(T_{\text{ex}}^{j})^{2} \frac{\partial \ln Z_{j}(T_{\text{ex}}^{j})}{\partial T_{\text{ex}}^{j}} - kT_{\text{h}}^{2} \frac{\partial \ln Z_{j}(T_{\text{h}})}{\partial T_{\text{h}}} \right] v_{\text{eh}} n_{\text{e}}$$
(14)

Energy conversion by elastic collision:

$$Q_{\rm e-h} = \sum_{j=1(j\neq e)}^{N} \frac{3}{2} k(T_{\rm e} - T_{\rm h}) \frac{2m_j m_e}{(m_j + m_e)^2} v_{\rm eh} n_e(15)$$

Effective reaction heat:

$$\Delta Q_{\ell} = E_{\text{reacl}} \left(k_{\ell}^{t} \prod_{i=1}^{N} n_{i}^{\beta_{i\ell}^{t}} - k_{\ell}^{t} \prod_{i=1}^{N} n_{i}^{\beta_{i\ell}} \right)$$
(16)

Paper review

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Fig. 3. Transient spatial distribution in the electron temperature and the heavy particle temperature between the electrodes in an SF₆ arc at RRRV=0.1 kV/ μ s.

Fig. 4. Electron density distribution in an SF₆ arc at RRRV=0.1 kV/µs.

A two-dimensional numerical thermo-fluid model of SF₆ are plasmas was developed with consideration of not only CNE effects but also 2T effects self-consistently. Two energy equations for electrons and heavy particles were separately solved to obtain the behaviors of electron temperature T_e and heavy particle temperature T_h . Results showed that 2T state and CNE effects were clearly seen in a residual SF₆ are plasma in case of TRV application with RRRV=0.1 kV/ μ s.

No compaison with LTE No final withstand calculation

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ARC JETS BLOWN BY OUTGASSING POLYMERS IN AIR (p99)

M. BECERRA¹,², A. FRIBERG2

Paper

review

¹ Royal Institute of Technology –KTH–, School of Electrical Engineering, 100 44, Stockholm,Sweden

² ABB Corporate Research, 722 66, Västerås, Sweden

This paper describes experimental results about the behaviour of arc jets transversely blown in the presence of outgassing polymers (POM –CH2O– or PMMA –C5H8O2–). The arc jets are ignited in air between copper electrodes under a

2 kA, 50 Hz AC current.

High speed photography and optical emission spectroscopy are used to study the mechanism leading to the increase of the arc voltage when polymers are used instead of non-ablating materials (e.g.quartz).

It is found that the transversal blowing flow caused by the injection of ablation vapours have a weak effect on the arc voltage build-up.

Instead, the chemical changes in the plasma environment appear to better explain the observed increase in the arc voltage when polymers are used.

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Contrary to measurements of optical emission from the arc column [5], the recorded spectra show clear differences in the chemical composition of the gas in front of the polymer surface for POM and PMMA

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NUMERICAL STUDY ON SELF-EXCITED OSCILLATION SWITCHING CURRENT IN HVDC MRTB (p207)

YANG LI, MINGZHE RONG, CHUNPING NIU*, YI WU, MEI LI AND FEI YANG State Key Laboratory of Electrical Insulation and Power Equipment, School of Electrical Engineering, Xi'an Jiaotong University, Xi'an 710049, China

Numerical study of current self-excited oscillations during the opening of HVDC metallic return transfer breaker (MRTB). The switching arc is simulated using **MHD theory coupled with the electric circuit variation** (previously, Cassie Mayr applications)

The calculated result gives **good agreement with the experiment**, and shows that the arc model can accurately simulate the current oscillation and the commutation process in MRTB.

Paper

review

The MRTB prototype is designed to break about 5.2 kA of DC current. The results from both simulation and experiment show that the current oscillation starts at about 16.5 ms and the total arc time is about 24 ms when the commutation capacitor bank and inductor are 72 μ F and 173 μ H, respectively.

This study can help improve the current interruption capability of MRTB.

$$\frac{\partial(\rho\phi)}{\partial t} + \nabla \cdot (\rho\phi\bar{v}) - \nabla \cdot (\Gamma_{\phi}\nabla\phi) = S_{\phi} \qquad \frac{1}{C}i_c + L\frac{d^2i_c}{dt^2} + R\frac{di_c}{dt} = \frac{du_{arc}}{dt}$$

MHD (Navier Stokes 2D - FLUENT) $i_c = i_c + i_c$

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Particular phenomenon

creating oscillations of

the arc (visible on tests

but not calculations)

at 16ms: cold gas

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July 6-11, 2014 - Orléans - France

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Workshop 1: Properties of thermal and quasi-thermal plasmas Chair: Dr Yann Cressault

Workshop 2: Electrohydrodynamic effects produced by corona, barrier and surface discharges Chair: Pr Eric Moreau

Workshop 3: Modeling of HV circuit breakers: where do we stand and what are the challenges

Chair: Dr Martin Seeger, Ph Robin-Jouan

Workshop 4: Major challenges in the diagnostics of non thermal plasma sources relevant for biomedical applications Chair: Dr Eric Robert

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Workshop 1: Properties of thermal and quasi-thermal plasmas Chair: Dr Yann Cressault

Transport properties :

- Anthony Murphy (CSIRO Materials Science and Engineering), Australia

Radiation :

- Kloc Petr (Centre for Research and utilization of Renewable Energy), Czech Republic

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Workshop 1: Properties of thermal and quasi-thermal plasmas Chair: Dr Yann Cressault

Radiation

2 different regions: arc core (dominating emission) and ext

- For SF6: maximum 10-15 frequency bands
- Non LTE: not necessary for current extinction (for high T; to be revised for small T applications)
- NEC:

if no interaction with Teflon nozzle, quite applicable If Teflon nozzle, great deviation since flux is badly calculated P1 or DOM is preferred (NEC deviation with pressure since absorption is increasing with pressure)

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Workshop 1: Properties of thermal and quasi-thermal plasmas Chair: Dr Yann Cressault

Transport coeffcients:

pour la composition, la communauté est d'accord pour dire que Potapov n'est pas correct Mais pour les autres propositions, il n'y a pas d'unanimité. VD Sanden ne semble pas non plus adapté.

Pour les hautes pressions, Viriel et Debye-Euckel corrections doivent être considérées.

Difficulté à mesurer la conductivité électrique, thermique et viscosité pour des mélanges thermiques, plus simple pour des gaz purs.

Présentations en annexe

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Workshop 3: Modeling of HV circuit breakers: where do we stand and what are the challenges? Chair: Martin Seeger/ Ph Robin-Jouan

Tuesday, 17:45-18:45

In the recent meeting of the Current Zero Club (http://www.currentzeroclub.org/) in Suzhou/China, a discussion was started about the quality of modeling of the physical process in High Voltage SF6 circuit breakers.

Discussed issues were for example:

- What is the importance of Non-LTE effects?
- How turbulence should be modeled?
- When should 3D effects be modeled?
- Material issues?

This discussion will be continued within a "gas inner circle" meeting at the GD2014, which is open to everybody who is interested in the topic.

High current phase

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- We can predict: arc voltage, pressure build up
- **Turbulence**: <u>small impact</u>, however important for mixing (e.g. exhaust, heating volume...); Turbulence model helps our simulation tools to converge and perhaps don't help us to understand turbulence
- No Phd about measurements or Direct simulation ٠
- The only way is to make comparisons between experiments and modelling: creation of a working group?
- **Non-equilibrium:** small impact (arc fringes only)
- **3D**: small impact in standard geometries (arc root attachment, 3D flow geometries, rotating arcs)
- **Erosion** from contact and nozzles \rightarrow important for pressure build up
 - Do we need to go forward in more detailed models ? Data are missing for the charge filled PTFE Vapours or particles are injected?

 - PTFE does not react to the spectra uniformly: this should be taken into account
- **Radiation**: P1 model delicate because of the boundary condition application. DOM very costly. Possible usage of hybrid model P1/DOM (depending on the bands). NEC simple rapid but needs to define arc radius; cylindrical approximation and absorption factor definition
 - Radiation spectra: everyone has his database: creation of a working group ? Data base to define for non-equilibrium conditions

Measurements: Radiation spectra: different sources but no unique solution Possibility to make dedicated benchmarks on simple mock up (precise conditions to define) Common research project for data bases with financial contribution could be addressed

Example for ABB result

Thermal interruption

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- <u>Not well predicted</u>
- **Turbulence**: decisive
- Non-equilibrium: probably large influence
 - Adding some streamer leader theory to get some full discharge prediction in a disequilibrium model (chemical and thermal)
 - Chemical equilibrium is more important from Tanaka's point of view
 - Very complicated model: is it possible to get it simpler ?
- **<u>3D</u>**: arc structure of 3D type
- **Erosion** from contact and nozzles \rightarrow copper vapor has influence on interruption
- Radiation: possibly some impact?
- <u>Measurements</u>: Reference experiments? Spectroscopy is the most adaptive mean to diagnostic current zero phase : proposal for shared campaign ?

Dielectric recovery

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- **<u>Prediction</u>**: E/N, streamer, leader
- Hard to measure the dielectric withstand for SF6 ; still validations are required
- <u>Turbulence</u>: great impact (early phase)
- Non-equilibrium: impact ?
- **<u>3D</u>**: great impact (exhausts,...)
- Erosion from contact and nozzles → vapor has influence on interruption and needs to be taken into account (specially GCB)
- <u>Radiation</u>: less relevant
- Measurements: Reference experiments?

Example for ABB result

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GD 2014 - Scientific Programme

Original paper no.	New paper no.	Scientific Session	Speaker
25693	H-1	н	Y, Zhao
26142	B-13	B2	H. Rabat
26317	B-27	B4	X. Wang
26494	E-3	E1	Y. Deng
26883	J-2	J	V. D. Karaventzas
27061	A-34	A5	Y. Tanaka
27062	A-43	A6	T. Nakano
27154	B-28	B4	X. Wang
27162	C-11	С	C. Mogarvey
27214	A-24	A4	P. Kloc
27233	A-20	A3	M. M. Walter
27241	B-21	B4	L Llu
27244	B-19	B3	D. Xlao
27248	E-14	E2	Y. Yasaka
27296	B-2	B1	A. Chollet
27307	A-4	A1	J. Llu
27338	A-9	A1	S. Pawar
27342	C-2	С	A. Chaikha
27347	A-14	A2	Q. Zhang
27348	E-4	E1	S. Aleferis
27359	A 32	A5	M. Iwata
27360	J-7	J	X. Wang
27361	A 17	A3	M. Kotari
27362	A-11	A2	T. Takematsu
27364	F-9	F2	H. Zerrouki
27374	D-9	D2	A. Ustimenko
27376	D-8	D2	A. Ustimenko
27427	C-5	С	S. Chen
27428	J-1	J	G. Jones
27429	D-17	D3	A. Yang
27430	F-6	F2	T. Sakoda
27431	A-38	A5	L. Zhong
27434	K-7	K	L. Wel
27437	B-22	B4	D. Xlao
27447	K-4	K	S. Qin
27450	A-16	A2	J. Spencer
27451	I-1		O. Kravchenko
27453	K-2	K	Y. Deng
27461	C-9	С	Y. Fu
27466	F-13	F3	K. L. Pan
27467	A 13	A2	J. Zhang
27471	A-7	A1	J. Krowka
27474	F-2	F1	K. L. Pan
27477	F-5	F2	G. Wattleaux
27480	A-1	A1	F. Yang
27481	A-30	A4	Y. Wu
27484	C-1	С	Y. Wu
27485	L-1	L	I. Kosarev
27487	K-3	K	A. Chicheportiche
27489	L-2	L	I. Kosarev

Original	New	Scient	
onginal	paper	iffic .	Speaker
aper no.	no.	Sessi	
27492	A-22	A4	P. Freton
27498	B-6	B1	H. Hoft
27502	K-11	K	W. Wang
27503	B-3	B1	J. Jones
27504	C-3	С	W. Wang
27506	A-49	A6	Y. Inada
27507	A-3	A1	E. Panousis
27508	E-11	E1	C. Chang
27510	D-12	D2	J. Mougenot
27511	A-5	A1	F. Yang
27512	A-26	A4	Y. Pel
27514	B-9	B1	P. Amold
27516	E-9	E1	s. stepanov
27517	D-15	D2	F. Clément
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27522	A-21	A4	J. schmiedberger
27524	M-7	M1	X. 2100
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27529	M-3	M1	C. LEU
27552	12	1	O. Mavchenko
2/561	A-40	Ab	T. Cressault
2/600	M-4	M1	M. Zhu
2/000	A-4/	AD	A. U.
2/60/	A-19	AJ	K. Zhu
2/624	- D-O	DI	n. ueno
27626	A-0	A1	A. LI
27635	J-0	1 11	G. Walledux
27630	NFT A 10	MI	3. Aleieis
27639	A-12	~~	M. Set0
27045	E-4	N	M. HIDEL
27720	E.6	<u>F</u> 2	D. Chapon
27753	A-10	A2	F. Field
27816	D-11	D2	C Distort
27817	D-10	D2	S. Wetzeler
27864	K-10	K	C. M. Franck
27947	D-14	D2	J.Y. Trepanier
27948	A-29	A4	P. G. Nikolic
27950	.1.6	1	P.G. Nikolic
27981	B-16	B2	E. Fourré
28008	A-46	A6	A. Coulbols
28105	A-42	A6	M. Baeva
28139	D-13	D2	C. Rond
28148	A-48	A6	R Putzu
28232	A-28	A4	M. Weuffel
28234	E-8	E1	J. F. Lagrange
28274	A-33	AS	G. Asanuma
28316	1-3	1	C. Zaepffel
28346	B-7	B1	A. Bouarouri
28380	B-8	B1	R. Tirumala

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paper	paper	Section	Speaker
no.	no.	Jession	
28391	B-4	B1	R. Mathon
26492	B-26	84	Y. Geng
28498	C-8	С	H. Iwabuchi
28501	K-6	K	H. Akashi
28502	A-27	A4	D. Elchhoff
28505	B-1	B1	O. Ducasse
28506	B-17	B3	R. Waters
28509	F-1	F1	O. Elchwald
28510	B-12	B2	G. Huang
28511	C-7	С	Z. L. Petrovic
28513	A-15	A2	S. Gorchakov
28515	C-10	С	A. Taran
28532	M-2	M1	C. Duluard
28543	B-20	B3	I. Adamovich
28549	B-15	B2	C. Zhang
28552	A-31	A4	T. Yoshino
28555	B-25	B4	K. Bayoda
28558	J-4	J	S. Arumuqam
28562	A-44	A6	A. Maslani
28565	M-8	M2	A. Petin
28566	D-19	D3	Z.L. Petrovic
28567	F-7	F2	Y, Zhao
28568	E-8	F2	S Iseni
28570	F-2	F1	N Skoro
28572	A-8	A1	M. Becerra
28573	K-5	ĸ	E Elimonova
28574	B-24	B4	S Okada
28575	A-41	A6	Y XIa
28576	A-39	46	Y. Okano
28578	K-8	K	N Donov
28579	A-2	A1	A B Mumby
28580	1.3	1	A B Mumby
28584	B-18	B3	K Takahashi
28585	6.2	G	M Hoon
28586	B-11	82	H Mu
28587	B-29	B4	E Moreau
28500	0.5	<u> </u>	D Tanaka
28591	D-18	03	I Yu
28504	153	E2	S Hasse
28598	A-45	A6	F Valensi
28599	D-20	03	S Stenanyan
28600	14	-	E Valensi
28604	D.C.	D2	S Leonov
20001	123	02	K Chatelain
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20000	10		C Laurent
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28616	A-36	A5	K. Tomita
28637	E-10	E1	F. Gherendi
28656	E-13	E2	W. P. Sun
28657	K-1	K	S. R. Sun
28669	D-7	D2	V. Felx
28670	F-11	F3	A. Khacef
28671	F-12	F3	A. Khace
28678	D-5	D2	J. Gruber
28682	F-10	F3	T. Damy
28707	A-18	A3	B. Schottel
28708	E-1	E1	M. Mikikian
28726	A-25	A4	T. Sakuyama
28731	B-10	B2	K. Mehalaine
28736	G-1	G	D. Astanel
28737	D-2	D1	A. Farah Sougueh
28739	A-23	A4	Q. Castillon
28740	J-3	J	S. Pellerin
28743	M+6	M1	N. Cerqueira
28744	D-16	D3	P. Escot Bocanegra
28750	E-12	E2	S. Cuynet
28763	E-15	E2	F. Dlop
28798	64	C	M. Kamarudin
28800	B-14	B2	J. S. Bolsvert
35817	M-5	M1	M. Kühn-Kauffeldt
40040	D-4	D1	D. Zhou

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	Scientific Session	Original paper no.	New paper no.	Speaker		Scientific Session	Original paper no.
		27480	A-1 A-2	F. Yang A. B. Murphy			28505
		27507	A-3 A-4	E. Panousis			27503
	A1	27511	A-5 A-6	F. Yang X II		B1	27624
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		28513 27450	A-15 A-16	S. Gorchakov J. Spencer			28549 27981
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		27606	A-47 A-48	X. LI R. Putzu			
		27506	A-49	Y. Inada			

5 0	Original	New	
	paper	paper	Speaker
	no.	no.	
	28505	B-1	O. Ducasse
	27296	B-2	A. Chollet
	27503	B-3	J. Jones
	28391	B-4	R. Mathon
	27624	B-5	H. Ueno
	27498	B-6	H. HOT
	28346	8-7	A. Bouarouri
	28380	8-0	R. Tirumaia
	2/514	D-9	P. Alfiold
	20/31	8-10	N. Menalaine
	20300	8-12	G Huang
	20010	B-13	H Rahat
	28800	B-14	J S Bolsvert
	28549	B-15	C Zhang
	27981	B-16	E. Fourré
_	28506	B-17	R. Waters
	28584	B-18	K. Takahashi
	27244	B-19	D. Xlao
	28543	B-20	I. Adamovich
	27241	B-21	L. Llu
	27437	B-22	D. Xlao
	28610	B-23	F. Pontiga
	28574	B-24	S. Okada
	28555	B-25	K. Bayoda
	28492	B-26	Y. Geng
	26317	B-27	X. Wang
	27154	B-28	X. Wang
	28587	8-29	E. Moreau
	27484	C-1	Y. WU
	27342	0-2	A. Chaikha
	27504	C-3	W. Wang
	28798	0.4	M. Kamarudin
	2/92/	0.0	a. urien D. Tanaka
	20090	0-6	2. I dilata 7. I. Detrovie
	20311	6.8	H wabuchi
	20490	6.0	Y Bu
	28515	C-10	A Taran
	27162	C 11	C. Mccarvey
-	28606	D-1	L Chauvet
	28737	D-2	A Earah Souqueh
	28604	D-3	K. Chatelain
	40040	D-4	D. Zhou

Orléans - France

Scientific	paper	paper	Speaker
Jession	no.	no.	
	28678	D-5	J. Gruber
	28601	D-6	S. Leonov
	28669	D-7	V. Felix
	27376	D-8	A. Ustimenko
	27374	D-9	A. Ustimenko
D2	27817	D-10	S. Wetzeler
	27816	D-11	G. Pletsch
	27510	D-12	J. Mougenot
	28139	D-13	C. Rond
	27947	D-14	J. Y. Trepanler
	27517	D-15	F. Clément
	28744	D-16	P. Escot Bocanegra
	27429	D-17	A. Yang
D3	28591	D-18	L. Yu
	28566	D-19	Z. L. Petrovic
	28599	D-20	S. Stepanyan
	28708	E-1	M. Mikikian
	28570	E-2	N. Skoro
	26494	E-3	Y. Dena
	27348	E-4	S. Alelferis
	27729	E-5	P. Chapon
E1	28605	E-6	R. Joussot
	28609	E-7	A. Klochko
	28234	E-8	J. F. Lagrange
	27516	E-9	S. Stepanov
	28637	E-10	F. Gherendi
	27508	E-11	C. Chang
	28750	E-12	S. Cuynet
_	28656	E-13	W. P. Sun
E2	27248	E-14	Y. Yasaka
	28763	E-15	F. Dico
	28509	F-1	O. Elchwald
F1	27474	1-2	K. L. Pan
	28594	F-3	S. Hasse
	27721	F-4	K Masur
	27477	F-5	G. Wattleaux
F2	27430	F-6	T. Sakoda
	28567	17	Y Zhao
	28558	5.8	S Icani
	20000	1.0	H Zerrouki
	2/304	5.40	T. Domu
	28682	F-10	1. Damy
F3	28670	F-11	A. Mader
	28671	r-12	A. Mader
	27466	1-13	K. L. Pan

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Spession paper no. Speaker no. Speaker no. G 28736 G-1 D. Astanel 28585 G-2 M. Hogg H 25693 H-1 Y. Zhao 1 27552 I-2 O. Kravchenko 28316 I-3 C. Zaepffel 27428 J-1 O. Kravchenko 28585 J-2 V. D. Karaventzas 26833 J-2 V. D. Karaventzas 26740 J-3 S. Pelierin 28558 J-4 S. Anumugam 27519 J-5 S. Stepanov 27950 J-6 P. G. Nikolic 27360 J-7 X. Wang 27627 J-8 G. Wattleaux 28607 J-9 C. Laurent 28657 K-1 S. R. Sun 27427 K-4 S. Olin 27453 K-2 Y. Denq 27447 K-4 S. Olin 28501 K-3 A. Chicheportiche <td< th=""><th>Scientific</th><th>Original</th><th>New</th><th></th></td<>	Scientific	Original	New	
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