Finite Element Simulation Of Impulse Arc Discharge

A. Chusov[1], E.Rodikova[1], M.Pinchuk[2], Y. Murashov[3], V. Frolov[3], D. Ivanov[3]
1. Streamer Electric Inc., St.Petersburg, Russia
2. Institute for Electrophysics and Electrical Power, St.Petersburg , Russia
3. St.Petersburg Polytechnical University, Russia

INTRODUCTION: Damages caused by lightning overvoltages remain to be an important issue for electrical industry, putting limitations for efficiency of transmission and distribution of electrical energy. Modern solutions for lightning protection such as multi-chamber arresters (MCA) for overhead powerlines (OHL) and surge protection devices (SPD) for electrical equipment are aimed to interrupt grid current initiated by lightning overvoltage. Such devices usually contain spark gap aimed to pass both lightning current and power grid current when the overvoltage is occurred and after-breakdown conducting channel is formed. In order to develop the optimal construction and provide reliable operation understanding of impulse arc discharge phenomena is of great importance.

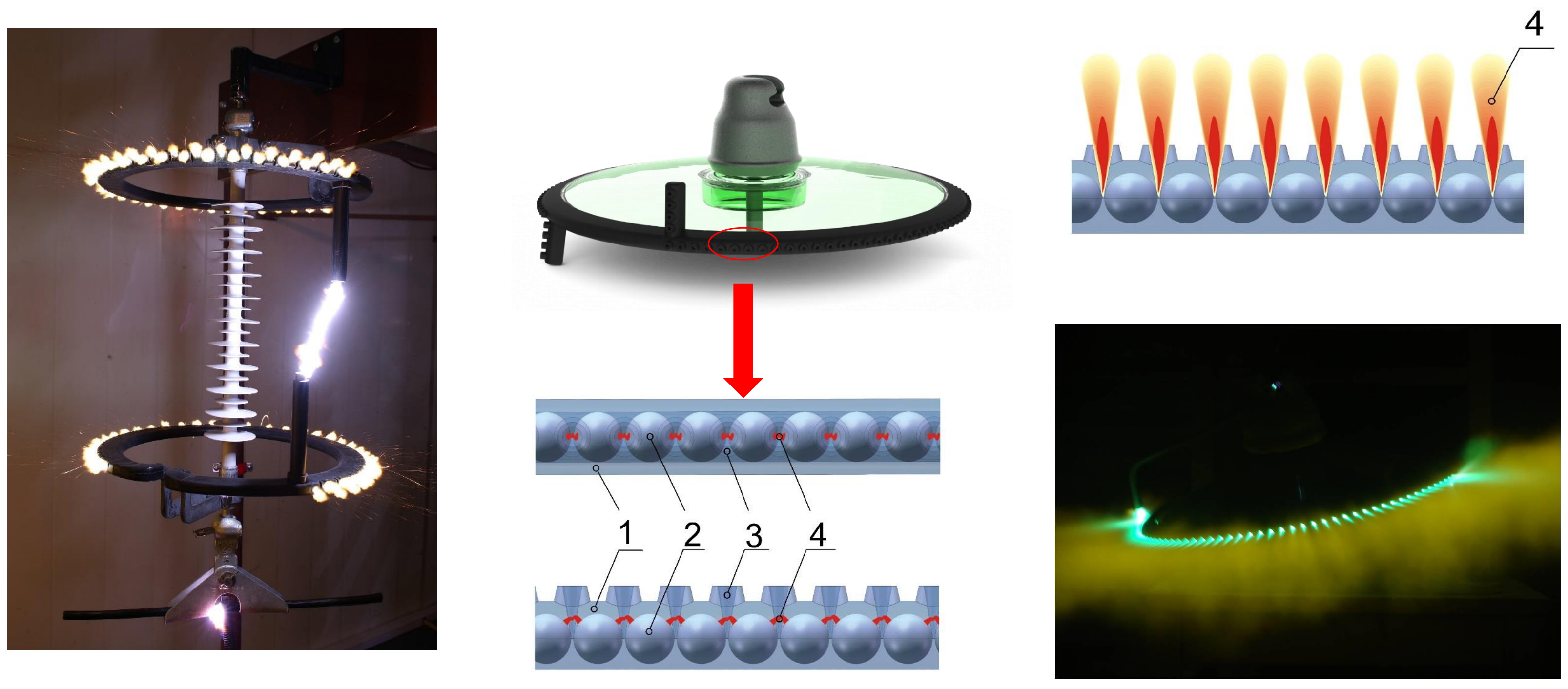

Figure 1. Multichamber arrester (MCA), 1 – silicone rubber length; 2 – intermediate electrodes; 3 – arc quenching chamber;4 – discharge channel.

COMPUTATIONAL METHODS: Impulse arc's physical model based on single fluid MHD equations. Influence of radiation is assessed using conventional radiation transport equation (RTE) for two-band model. Standard k −ε turbulence model is realized.

$$\frac{\partial\rho}{\partial t}+\nabla\cdot\{\rho\mathbf{v}\}=0$$

$$\frac{\partial(\rho\mathbf{v})}{\partial t}+\nabla\cdot\{\rho\,\mathbf{v}\otimes\mathbf{v}\}=-\nabla p+\nabla\cdot\mathbf{T}+\mathbf{j}\times\mathbf{B}$$

$$\frac{\partial(\rho H)}{\partial t}+\nabla\cdot\{\rho H\mathbf{v}-\lambda\nabla T\}=\frac{\partial p}{\partial t}+\nabla\cdot(\mathbf{T}\cdot\mathbf{v})+\mathbf{j}\cdot\mathbf{E}-\nabla\cdot\mathbf{F}$$

$$\mathbf{j}=\sigma(\mathbf{E}+\mathbf{v}\times\mathbf{B})$$

$$\nabla\times\mathbf{B}=\mu_0\mathbf{j}$$

$$\partial_t\mathbf{B}+\nabla\times\mathbf{E}=0$$

The two-dimensional axisymmetric model with the different current amplitudes (3, 10, 20, 30 kA) is calculated.

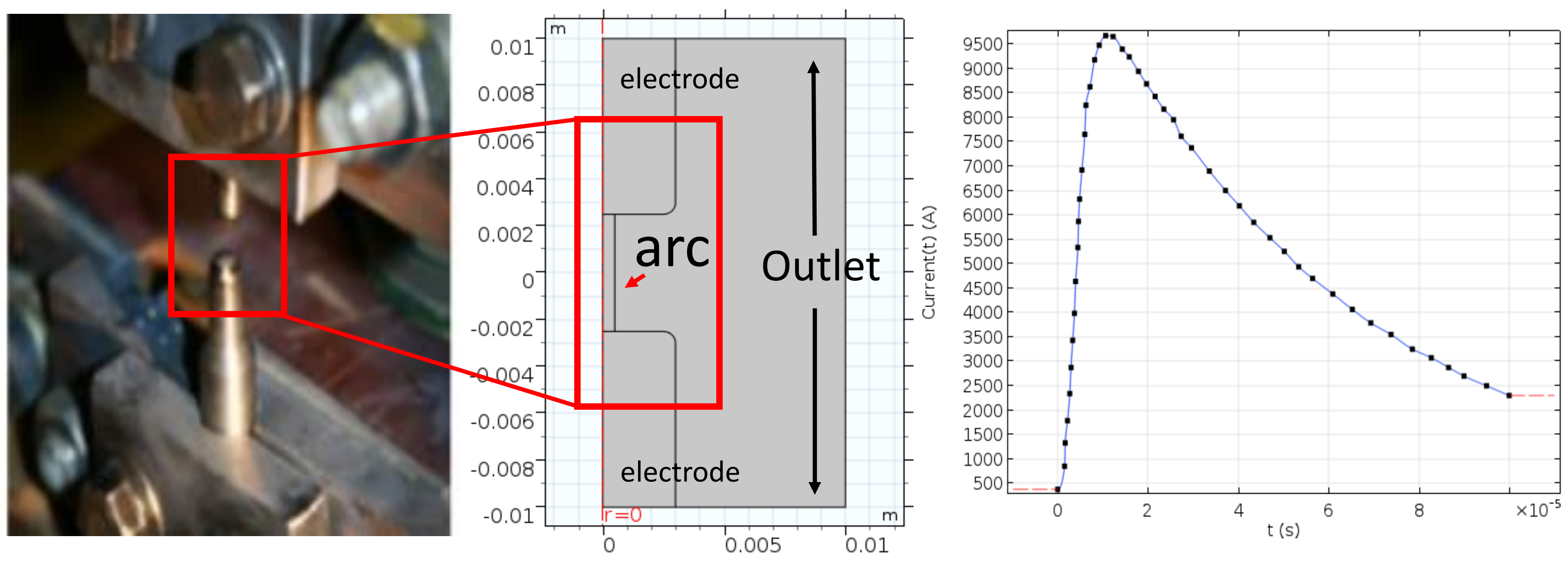

Figure 2. Geometry of model and experimental impulse of current

High Mach Number Flow (HMNF) was applied to resolute shock front, solution of for two frequency bands RTE was performed with Radiation in Participating Media (RPM) module. Smoothed aggregation Algebraic Multigrid (AMG) solver was chosen in order to tackle the strong nonlinearity if the problem.

RESULTS: At the 10 μs the temperature is about 25 000 K, the pressure is about 10 atm, and the gas is taken out of the gap.

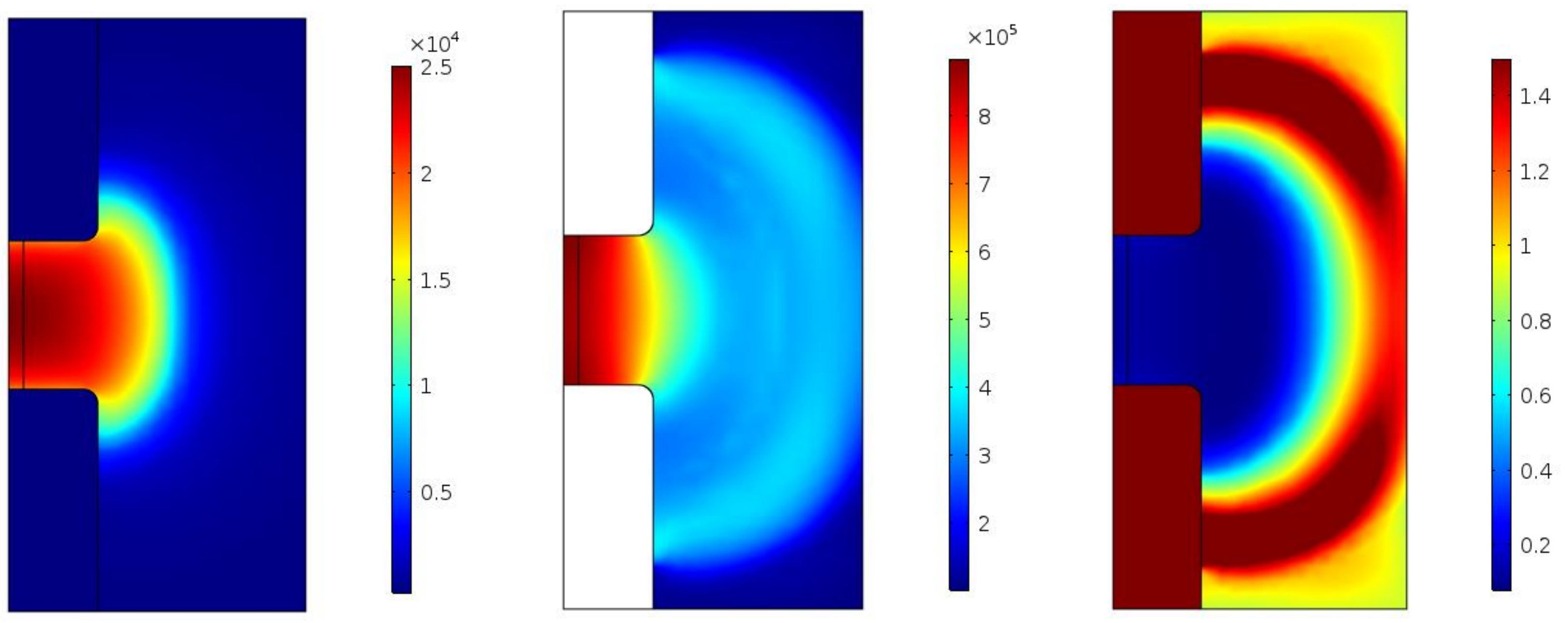

Figure 3. Temperature (right, K), pressure (middle, Pa) and density (left, kg/m^3) distribution at 10 μs for 20 kA

As a result it's possible to compare experimental and calculated voltage with the different assumptions. As an example the comparison between computer simulation of laminar flow and turbulent flow with the Lorentz force are shown on the Figure 4 .

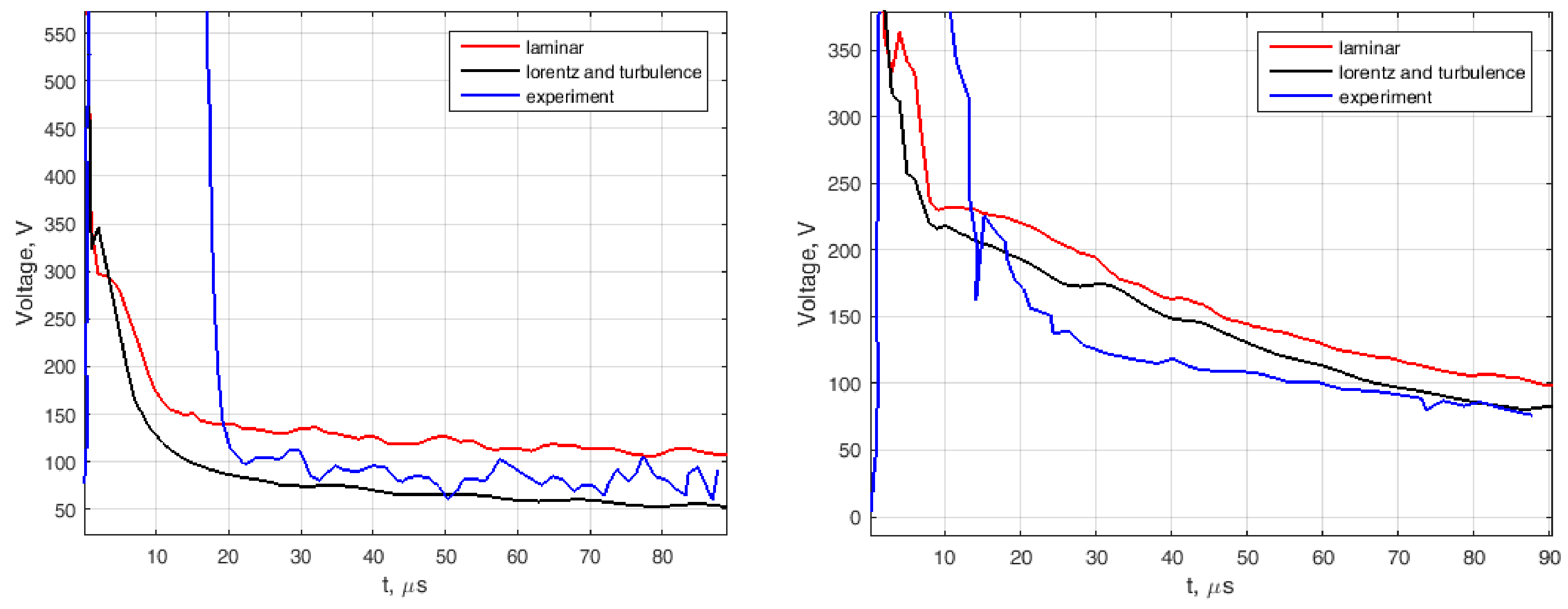

Figure 4. Gap voltage for different current amplitudes: 10 kA (right) and 30 kA (right)

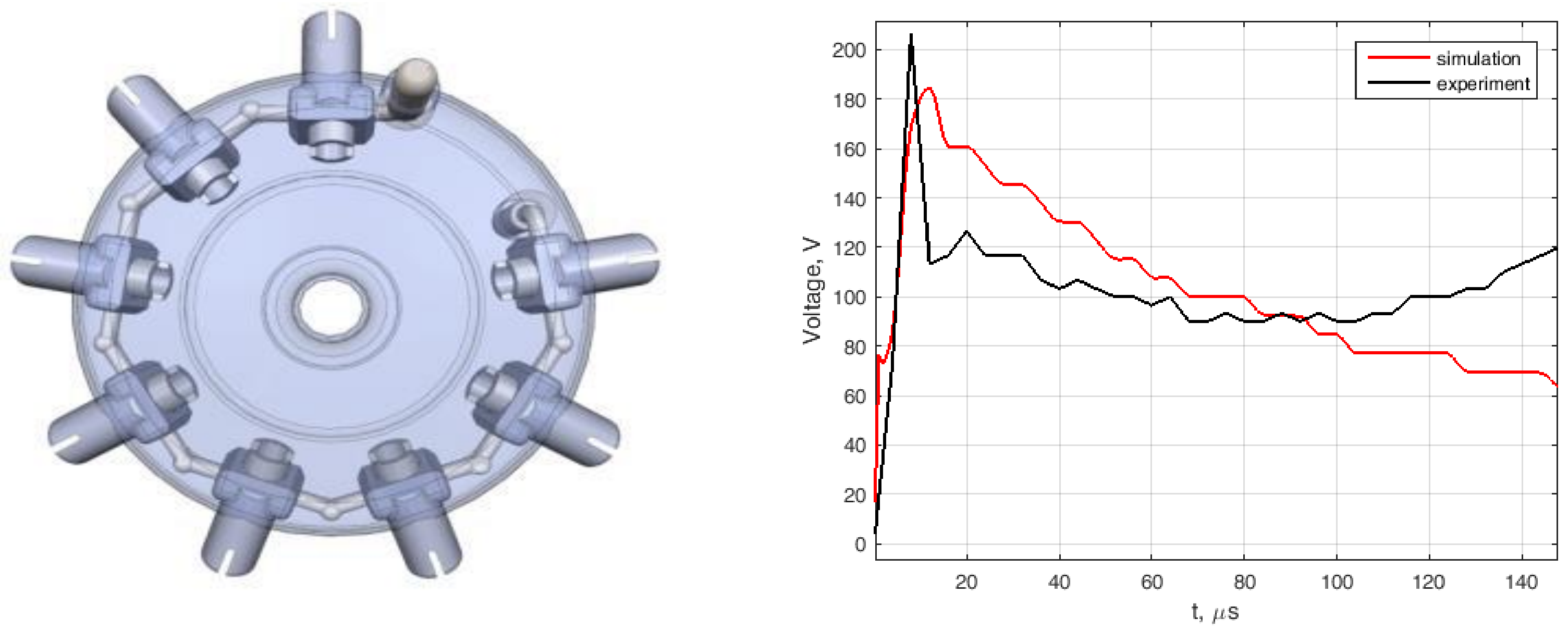

Figure 5. Multi-chamber system(MCS) (left) and comparison between simulation and experiment (right)

CONCLUSIONS: Obtained preliminary results of impulse arc simulation are in acceptable agreement with experimental data. Possibility of application of developed model for designing new prospective protection devices is assessed.

REFERENCES:

1. Mario Mürmann, Alexander Chusov, Roman Fuchs, Alexander Nefedov and Henrik Nordborg, Modeling and simulation of the current quenching behavior of a line lightning protection device, J. Phys. D: Appl. Phys. 50 (2017) 105203 (12pp)