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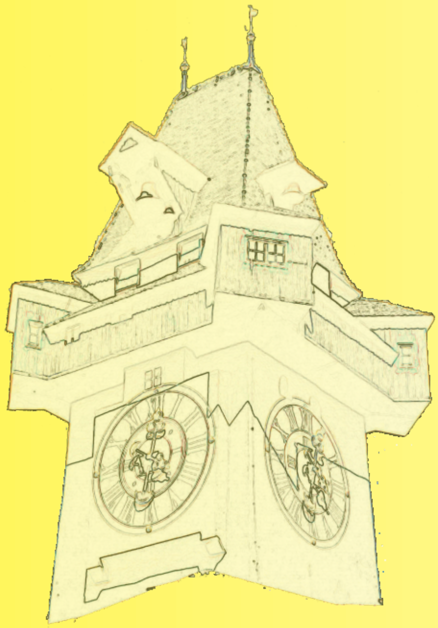
Abstracts



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Multiphysics Models of Innovative Actuators of LV and MV Vacuum Circuit Breakers

[1]Yevgen I. Bajda, [2]Markus Clemens, [1]Michael G. Pantelyat, [1]Serhii V. Vyrovets
[1]Department for Electrical Apparatus, National Technical University "Kharkiv Polytechnic Institute", Kyrpychova Str. 2, UA-61002 Kharkiv, Ukraine
[2]Chair of Electromagnetic Theory, University of Wuppertal, Rainer-Gruenter-Str. 21, D-42119 Wuppertal, Germany
E-mail: baida.kpi@gmail.com, clemens@uni-wuppertal.de, m150462@yahoo.com, vsv_2007@ukr.net

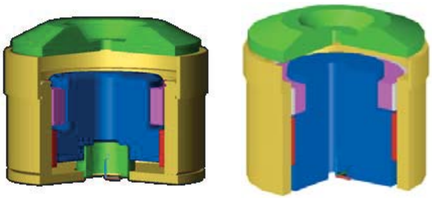
Abstract—**Based on a multiphysics model, a technique for a computer simulation of the actuators of vacuum circuit breakers is developed. The technique is based on static and transient calculations of the electromagnetic field in a nonlinear conducting and moving medium, taking into account the nonlinear equations of the electric circuit as well as the dynamics of the motion. The technique allows to analyze processes in complex electromechanical systems to develop innovative designs of actuators.**

***Index Terms*—Actuator, circuit breaker, computer simulation, multiphysics.**

I. Introduction and Problem Definition

Currently, for switching of LV and MV circuits, vacuum circuit breakers which have good arcing properties and high breaking capacity are widely used. One of the problems of creating the drive mechanism of such apparatus is the need to ensure the absence of contact welding when a through short-circuit current flows through them, which is achieved due to a certain amount of contact pressure. Experimental data show that at a switching current of 20 kA, the pressure must be at least 2000 N, or 6000 N for three poles. To counter such forces, electromagnetic or electromotor drives are used. Their main disadvantage is the presence of mechanical devices that ensure the fixation of contacts in the on position. As a rule, these are mechanical latches, which should reliably hold the mechanism in the on position, while requiring only small forces to release the free release mechanism when the circuit breaker is switched off (speed). The second method is fixing the mechanism with a special holding winding. However, it should be noted that both methods are difficult to implement and not reliable enough.

One of the ways to solve the problem is to create a drive based on monostable and bistable electromagnetic actuators with highly coercive permanent magnets that provide reliable fixation of the position of contacts, consuming network energy only in transient modes. The advantage of such actuators is the simplicity of design, reliability and simplicity of operation (Fig. 1). The simplicity of the design of the actuators is combined with the extremely complicated physical processes occurring in the system (transient electromagnetic field in a conducting nonlinear moving medium) to predict the result of which is not a priori possible.



a) *b*)

Figure 1: Actuators developed: *a*) – bistable actuator; *b*) – monostable actuator.

II. A Technique Proposed and Results Obtained

Therefore, in the investigation and design of such actuators, mathematical multiphysics models adequately reflecting the basic physical processes and allowing to significantly reduce the design time and save material resources in the manufacture of prototypes are required [1]. The proposed model is a system of differential equations describing physical processes: in a non-linear electrical circuit, an electromagnetic field in a non-linear conducting moving medium taking into account permanent magnets, and mechanical equations of the dynamics of a body with variable mass:

$$\begin{cases} U = R \cdot i + L \cdot \dfrac{di}{dt} + 2\pi \dfrac{N}{S} \cdot \displaystyle\int_V \dfrac{\partial A_\varphi(r,z,t)}{\partial t} \cdot r \cdot dr \cdot dz\,; \\ \sigma \cdot \dfrac{\partial \vec{A}}{\partial t} + \mathrm{curl}(\mu^{-1} \cdot (\mathrm{curl}\, \vec{A}) = \mathrm{curl}(\mu^{-1} \cdot \vec{B}_r) + \dfrac{i \cdot N}{S} \cdot \vec{1}_\varphi; \\ \dfrac{d(m \cdot \vec{v})}{dt} = \vec{Q}_m - \vec{F}; \\ \dfrac{ds}{dt} = \vec{v}; \end{cases}$$

where the usual notation has been used.

Figure 2 shows the results of calculation of a bistable actuator. The final force with a de-energized coil is 6590 N, which allows to keep the contacts of the circuit breaker in a closed position due to the energy of permanent magnets. The actuator is switched off when a reverse polarity signal is applied to the coil, which leads to a quick opening of the contacts under the action of contact springs' forces.

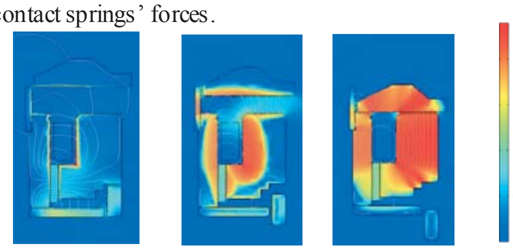


Figure 2: Bistable actuator: dynamics of the magnetic flux density module in the function of the armature position.

References

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