# THE DETERMINATION OF THE KINEMATICS PARAMETERS FOR OPERATING MECHANISM OF THE CIRCUIT BREAKER

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## 1. INTRODUCTION

In theory, the circuit breaker is considered to be a connecting mechanical device which is capable to establish, support and break the current in normal and abnormal conditions (short-circuit, overtension). The operating mechanism of the circuit breaker allows the movement of the mobile contact.

The main electrical problem of the circuit breaker is that it must extinguish the electrical arc with a minimum delay. On the other hand, at the opening of the electrical circuit, extinguishing the electrical arc depends on the speed and the stroke of the movable contact.

The dynamic model of the mechanical system has been presented in [6]. A way to determine the kinematic parameters of the movable contact of a high voltage circuit breaker has been presented in [1].

In this paper, the authors presents the dynamic analysis of the operating mechanism, as a way to find out the kinematic parameters of this mechanism contained inside of a circuit breaker with sulphur hexaflorid (***SF6***) and self compression.

## 2.DYNAMIC PARAMETERS OF THE OPERATING MECHANISM

Mechanical operating system of the movable contact is the crank slider mechanism. The structural schema and the operating system of the movable contact's mechanism are presented in the Figure 1.

The movable contact presents a movement of translation, so that is why in the dynamic study of the operating mechanism the reduction point dynamic model has been considered. The reduction point is a point attached by the moving contact (point ***C***) of the circuit breaker.

The parameters used by the reduction point dynamic model are, as follow: position and speed of the reduction point, reduced mass and reduced force [3], [4]. The position and the speed of the reduction point are determined using kinematic analysis.

The reduced mass is the equivalent of the mass of the operating mechanism concentrated in the reduction point and could be determined with the next relation:

$$m_{red} = \sum_{i=1}^{p}\left( m_i \cdot \left(\frac{v_{Gi}}{v}\right)^2 + J_{Gi} \cdot \left(\frac{\omega_i}{v}\right)^2 \right) \quad (1)$$

where: $m_i$ is the mass of the 'i' element; $v_{Gi}$ - the centre of mass velocity;

$v$ - the reduction point velocity;

$J_{Gi}$ - inertial moment of the 'i' link;

$\omega_i$ - angular velocity of the 'i' link.

The last dynamic parameter, reduced force, has two components: reduced motor force and reduced resistance force. The first of them, reduced motor force, is mainly represented by the force of a helical spring. This force operates on the crank linkage, determining the moment of force presented in the next relation:

$$M_1 = (F_1 + k \cdot \Delta L) \cdot AE' , \quad (2)$$

where: $F_1$ is pretension force of the helical spring;

$k$ - spring stiffness; $\Delta L$-deformation of the helical spring in relation to the initial position;

$AE$ - length of the connecting rod.

The reduced resistance force has as main component, the compressive force of the dielectric gas from the arc chute 'a' (Fig. 2).

For circuit breaker with SF6 and self compression, there are optimal condition for the arc extinction when the dielectric gas flow is nearly from the sonic velocity [5]. Therefore the operating mechanism has to achieve a pressure for dielectric gas which determine a dielectric gas flow velocity approached from sonic velocity. The compartments of the arc chute and main stages of the pressure dielectric gas for opening of the circuit breaker are presented in Fig. 2.

The value of the compressive force achieved for each stage of the opening circuit breaker is

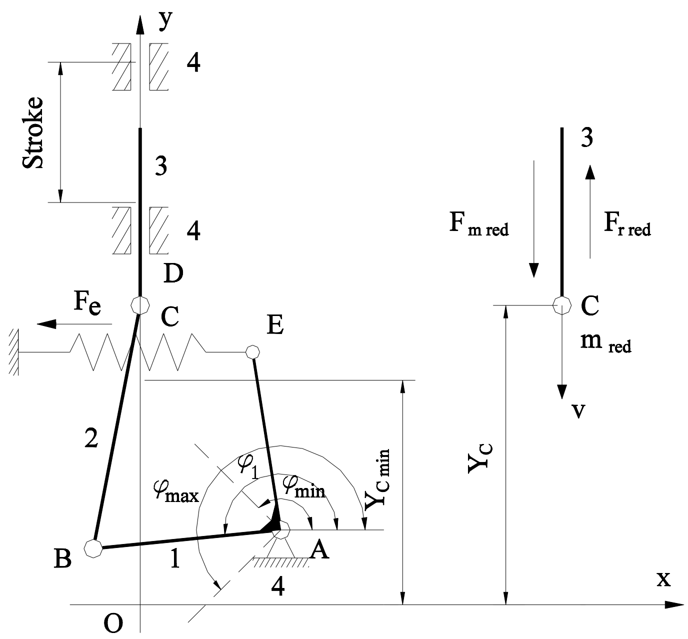


Fig. 1. Mechanism of the movable contact and the parameters of the dynamic model

given by relation:

$$F_p = p_{ak} \cdot S_{pa} - p_{bk} \cdot S_{pb} \,, \qquad (3)$$

where: $p_{ak}$, $p_{bk}$ are pressures from compartment 'a' and 'b' when piston is in position k;

$S_{pa}$, $S_{pb}$ - area of the piston from the compartment 'a' and 'b'.

The reduced motor and resistance force are computed with relation:

$$\overline{F}_{red} = \frac{\overline{M}_1 \cdot \overline{\omega}_1}{\overline{v}} + \frac{\overline{G}_1 \cdot \overline{v}_1}{\overline{v}} + \frac{\overline{G}_2 \cdot \overline{v}_2}{\overline{v}} + + \overline{G}_3 + \overline{F}_p + \overline{F}_f \,, \qquad (4)$$

in which: $M_1$ is driving moment achieved by helical spring; $\omega_1$ - angular speed of the crank link; $G_1$, $G_2$, $G_3$ - weights of the mechanism links; $v_1$, $v_2$ - centre of mass speed for the crank and rod linkage; $v$ - speed of the moving contact (reduction point); $F_p$ - compressive force for dielectric gas; $F_f$ - friction force between piston and arc chute.

The dynamic parameters determined will be used to establish the motion equation of the movable contact.

**3. Equation of motion**

Lagrange's equation was used to establish the equation of motion for movable contact. This equation is applied in dynamic model reduction point to obtain the kinematics parameters of the movable contact. On the base of the kinetic energy of dynamic model and Lagrange's equation, the equation of motion for movable contact may be written:

$$m_{red} \cdot \frac{dv}{dt} + \frac{v^2}{2} \cdot \frac{dm_{red}}{dy} = F_{red} \,, \qquad (5)$$

where:

$m_{red}$ is reduced mass;

$v$ - speed of the moving contact;

$dm_{red} / dy$ - differential of the reduced mass depending on the position parameter of the movable contact;

$F_{red}$ - reduced force.

The equation of motion is differential equation of order two. To solve this equation transforms into system of two differential equation by order one:

$$\begin{cases} \dfrac{dv}{dt} = \dfrac{1}{m_{red}} \cdot \left( F_{mred} - F_{r\,red} - \dfrac{1}{2} \cdot v^2 \cdot \dfrac{d\,m_{red}}{dy_C} \right) = f_1(t, y, v) \\ \dfrac{dy_c}{dt} = v = f_2(t, y, v)\ . \end{cases} \tag{6}$$

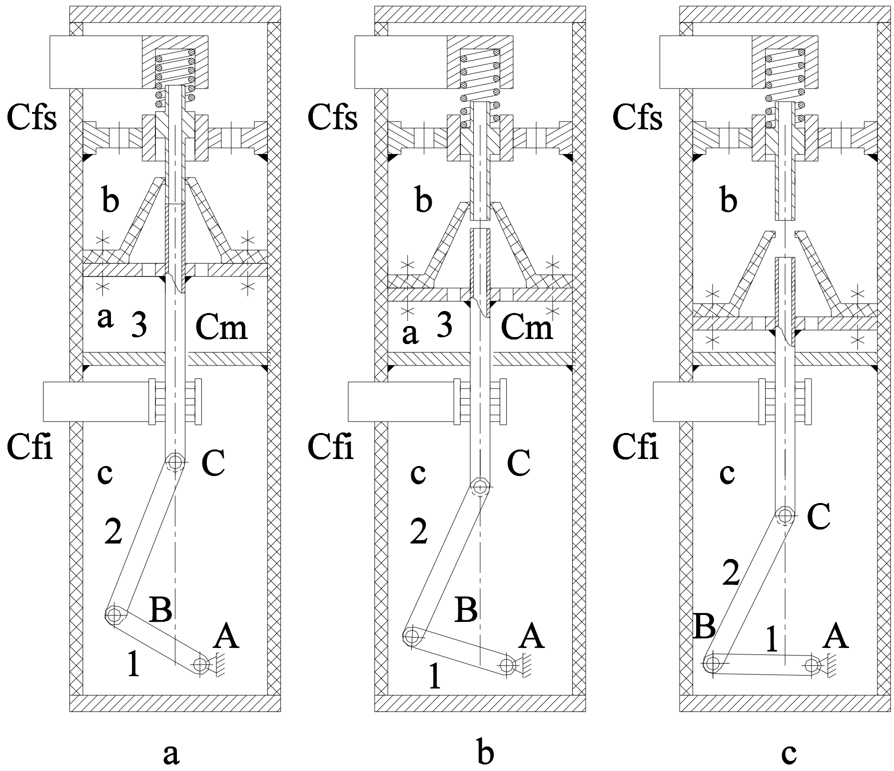


**Figure 2.** Compartment of the arc chute and main stage of the opening circuit breaker. ***Cfs*** - *upper fixed contact;* ***Cfi*** - *lower fixed contact;* ***Cm*** - *movable contact*

To solve the system of equation (6) was used Runge-Kutta numerical method. In this way, the parameter of position and speed of movable contact are determined by using the iterative relations:

$$\begin{cases} v_{i+1} = v_i + \dfrac{h}{6} \cdot (k_{11} + 4 \cdot k_{12} + k_{13}) \\ y_{C,i+1} = y_{C,i} + \dfrac{h}{6} \cdot (k_{21} + 4 \cdot k_{22} + k_{23}) \end{cases}, \tag{7}$$

in which:

***h*** is the step of integration;

$k_{ij}$ are the coefficients of integration computed with relation:

$$k_{i1} = h \cdot f_i\,(t_k, y_k, v_k);$$
$$k_{i2} = h \cdot f_i\,(t_k + h/2,\ y_k + k_{21}/2,\ v_k + k_{11}/2), \tag{8}$$
$$k_{i3} = h \cdot f_i\,(t_k + h,\ y_k - k_{21} + 2 \cdot k_{22},\ v_k - k_{11} + 2 \cdot k_{12}),$$

$i = 1,2.$

In relations (8), $f_i\,(t,y,v)$ represent the second term from system of equation (6).

## 4 NUMERICAL EXAMPLE

The dynamic model achieved was applied to movable contact mechanism of circuit breaker with SF6 and self compression. The geometrical parameters of the mechanism are: $x_A$ = 0.035 [m], $y_A$ = 0.0 [m], $L_1$ = 0.05 [m], $L_2$ = 0.24 [m]. The working of the movable contact mechanism is determined by a helical spring, which have following parameters: spring stiffness $k$ = 12500 [N/m] and pretension force $F_1$ = 520 [N].

To determinate the reduced motor and resistance forces, in any moment of opening operation, was achieved a compute program. The variation of these forces are presented in Fig 3.

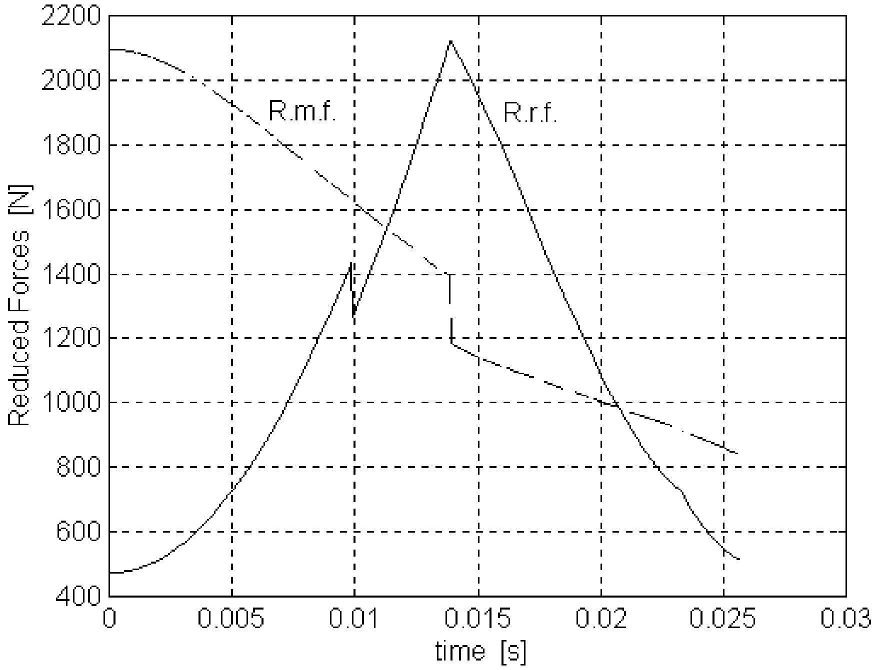


**Figure 3**. Reduced motor and resistance forces.

To numerical solve the equation of motion for operating mechanism was achieved a compute program. The initial conditions necessary to integrate the equation of motion are: $t = 0$,
$y = 0.27$ [m], $v = 0$.
The integration equation of motion results are the distance between the position movable contact and these position, when the circuit breaker is opening and the movable contact speed depending on time. The variation of the kinematics parameters of the movable contact depending on time are presented in Figs. 4 and 5.

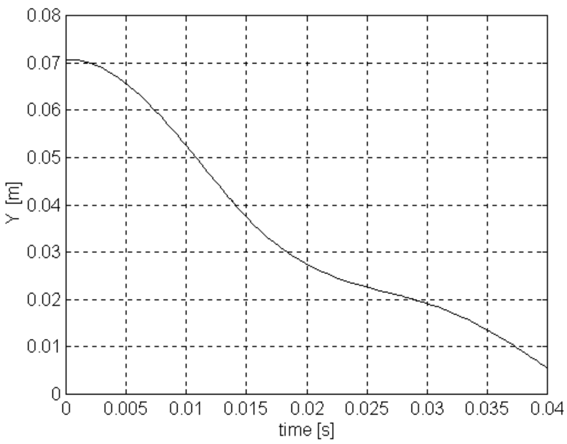


**Figure 4**. Parameter of position

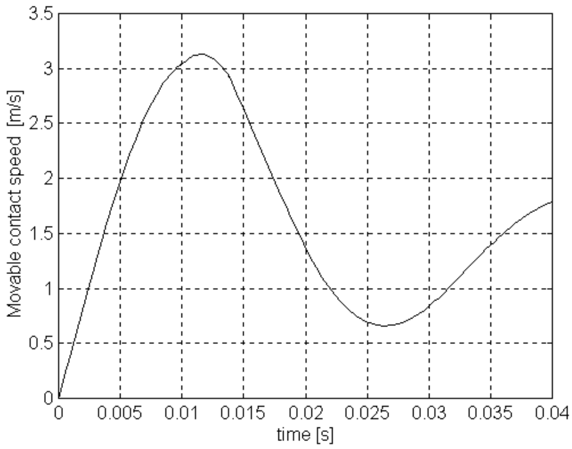


**Figure 5.** Movable contact speed

The diagrams from Figs. 4 and Figure 5 allow to establish the moment in which the movable contact achieve the imposed speed ($v$ = 1.5 [m/s]) by the electrical condition and it position in this time.

## 5. CONCLUSION

The work of the operating mechanism is determined by a helical spring. In this case, the cinematic parameters of the crank are not established and so the position and speed of movable contact are not determined. To determinate the cinematic parameters of the movable contact there was achieved a dynamic model. This model permits to establish the pressures of de compartment of the arc chute.

The result of the dynamic study of the operating mechanism is a mathematics model for the moving contact motion, which allow to simulate this motion.

The mathematical model may be used in circuit breaker design and to improve the mechanical parameters. The cinematic parameters of the moving contact obtained by solving the equation of motion are necessary to verify if there are satisfied the electrical conditions for opening operation.

## *References*


*1. **Calin, Ghe., Calin, E., Filimon, C**., Stabilirea ecuaţiei de mişcare a contactului mobil al întreruptorului de înaltă tensiune acţionat cu mecanism oleopneumatic, Electrotehnica, vol.36,nr.8, 1988, p.297-303.*

*2. **Culafic, G.,** Optimal Dynamic Synthesis of a Current Circuit Breaker Mechanism, Ninth World Congress on the Theory Machine and Mechanism, Milano 1995, vol.2, p.891.*

*3. **Duca C.,** Mecanisme, Rotaprint I.P.Iaşi, 1983.*

*4. **Merticaru, V.,** Probleme dinamice ale funcţionării mecanismelor, E. Junimea, Iaşi, 1991.*

*5. **Ryan, H.M., Jones, G.R**., SF6 Switchgear, London, 1989.*

*6. **Skreiner, M., Barkan, P**., On a Model of a Pneumatically Actuated Mechanical System, Journal of Engineering for Industry, feb., 1971, p.211.*