Dynamic Simulation of Mini circuit breaker

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Key words: contact; mini circuit breaker; ADAMS

Abstract. Because the breaking characteristics of contacts decide the reliability of miniature breaker, it is necessary to study it. In this paper, the mathematic theory is firstly elaborate. And the 3D model of contacts is built after that. Based on virtual prototyping technology, the breaking characteristic in different short circuit current is obtained by use of ADAMS.

Overview

Miniature circuit breaker is a key component in low voltage distribution network. It could break the fault current based on the work performance of devices. It could protect the grid and prevent the fault expanding [1]. With economic development, increasing demand for power generation capacity, distribution system reliability has become even more important, so that further action features and protection MCB put forward higher requirements. As a molded case circuit breaker, although small, but its structure and working principle is not simple, especially short-circuit breaking MCB process is extremely complex. Therefore, this paper uses software to explore the contact performance in short-circuit breaking.

Math Model

The internal structure of miniature circuit breaker is complex, and the inner force on the structure is changing with the short circuit current. Hence, the general method is difficult to study the dynamics [2]. This paper uses the current design and manufacturing areas of new technology - virtual prototyping technology to multi-body dynamics simulation software ADAMS as a platform for small circuit breaker contacts dynamics simulation.

Generalized coordinates are Cartesian coordinates of the centroid and the reaction rigid rigid orientation Euler angles *i* ADAMS software in the composition, i.e., $q_i=[x,y,z,\Psi,\theta,\Phi]_i^T$,$q=[q_1^T\ldots q_n^T]^T$. Lagrange multiplier method to establish the system equations of motion:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}}\right)^T-\left(\frac{\partial T}{\partial q}\right)^T+f_q^T\rho+g_{\dot{q}}^T\mu=Q \tag{1}$$

The equations of motion system are as shown in Formula (1), and the complete constraint equation is $f(q,t)=0$. The nonholonomic constraint equation is $g(q,q,t)=0$; T is the kinetic energy of the system; Q is generalized coordinate system array; ρ is the complete corresponding constraint Lagrange multiplier array.

ADAMS model based on the system automatically creates system Lagrange equations of motion for each rigid lists Lagrange equation and the corresponding constraint equations with generalized coordinates corresponding multipliers [3]:

$$\begin{cases}\dfrac{d}{dt}\left(\dfrac{\partial K}{\partial \dot{q}_j}\right)-\dfrac{\partial K}{\partial q_j}+\sum_{i=1}^{n}\dfrac{\partial \Phi_i}{\partial q_j}\lambda_i=F_i\\ \Phi_i=0\end{cases} \tag{2}$$

In formula (2), i=1,⋯,n, j=1,⋯,m; q_j-described generalized coordinates system;Φ_i -constraint

equations of systems; F_i-generalized force in coordinate direction; λ_i -Lagrangian multiplier. Formula (2) can also be written:

$$\begin{Bmatrix} F \\ \Phi \end{Bmatrix} = \{0\} \tag{3}$$

The kinetic energy of the system is defined as a rigid body:

$$K = \frac{1}{2}\dot{r}^T m\dot{r} + \frac{1}{2}\omega^T m\omega \tag{4}$$

The kinetic energy into the form of a simple matrix of formula (3), the synthesis is as follows:

$$M\ddot{x} = \Phi_x^T \lambda = Q^* \tag{5}$$

For the above algebraic equations, solving the first down before ADAMS second order differential equations into a first-order differential equations. ADAMS will be all that is written in a Lagrangian-order differential equations are situations, introducing $u=dq/dt$, obtain the following forms:

$$\begin{Bmatrix} F \\ \dot{q} - u \\ \Phi \end{Bmatrix} = \{0\} \tag{6}$$

Actual Models and Simulation Process

Contacts system includes dynamic and static contacts. The static model is easy; it is composed by two rectangles [4]. The dynamic contact is more complicated, can be seen by splitting moving contacts section has two parts, one is the moving contact with a conductive rod, the other is connected by a spring attachment contacts with contacts, contacts attachments is stuck in front of the locking member opening[5].

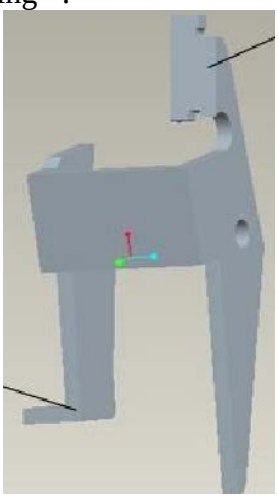

Fig.1 Contact attachment

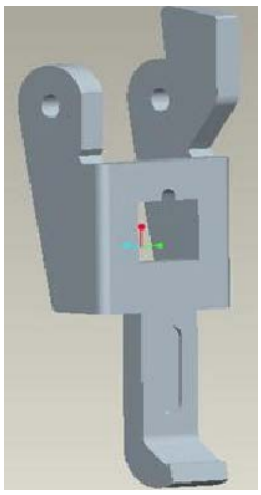

Fig.2 Dynamic contact model

ADAMS simulation steps:

①Model Construct

For creating a system model, software internally ADAMS/View module could be used, which provides a wealth of internal basic shape tool library, such as rectangular, cylindrical, and spherical. Boolean operators can also use to form a complex combination of basic. Parts created mainly rigid body and flexible body mass point, the system will automatically add mass, density and other physical inertia to establish good parts according to the default value is set, the user can modify these parameters as needed.

②Constraints of Prototype

A system usually consists of a number of component parts, between these components are not isolated, but there is a certain constraint relations that limit movement of one part to another part of this constraint between two parts relationship or constraint deputy vice-called sport. Therefore, in

order to prevent relative movement between these parts, these parts need to add constraints between the sub, the sub may be determined by these constraints, and the movement of the connection between objects. But for the system in motion, you also need to add drivers and loads deputy campaign on the drive is also essentially a constraint, but this constraint is driven by two parts by a specific relations campaign.

③Test and Verification

After completing the above setup, the initial prototype model simulation, by observing their movement, and compared with the real movement, check the prototype model is correct, if the actual movement of a lot of difference, it is necessary to identify problems lies, repeatedly modify the model size, until close to the real movement. In the course of the prototype model of the motion simulation, ADAMS software model of a component can be calculated displacement, velocity, acceleration, etc., can also be measured by the method of testing some of the more easily measured data, compared with the simulation data, which is one way to verify the correctness of the model.

④ Refine the model and simulation analysis

Preliminary simulation analysis can determine the validity of the model is basically the next step to add more complex parameters in the model, to refine the model, these parameters include increasing friction between objects, such as the rigid to flexible body.

Simulation Results

① Lower handle force contact closure process simulation

Figure 3 is a different handle force (①, ②, ③ representing 5N, 7N to 10N of a handle force) characteristics in the contact velocity.

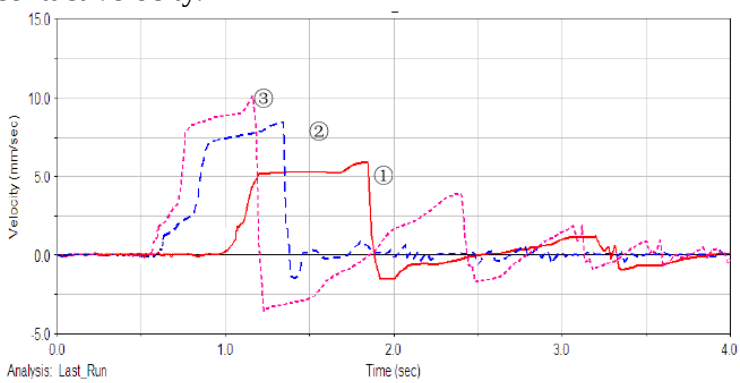

Fig.3 Different contacts speed characteristics in handle force

Figure 3 shows that with increasing grip force, contact closure process time will be reduced, when the handle force of 5N when the contacts are closed after the movement, there was a slight rebound, not too stable; When the handle force 7N when, after the static and dynamic contact closure, almost no rebound, can be said to be stable contact, saw handle force at this time is an ideal closing force; when the handle force of 10N, the contacts are closed after the movement, there is a large the rebound is unstable, because the handle force, closing speed, the larger the impact moving contacts static contact force, the rebound is more serious.

②Contact breaking process simulation under short-circuit conditions

Short-circuit the process of breaking contacts with the electromagnetic force and the electric repulsion relevant contacts, Figure 4 is a displacement and velocity into account the characteristics of the contacts on the electric repulsion when the contacts, the components of the maximum short circuit current period were taken 500A, 750A and 1000A The solid line - displacement, dashed - speed.

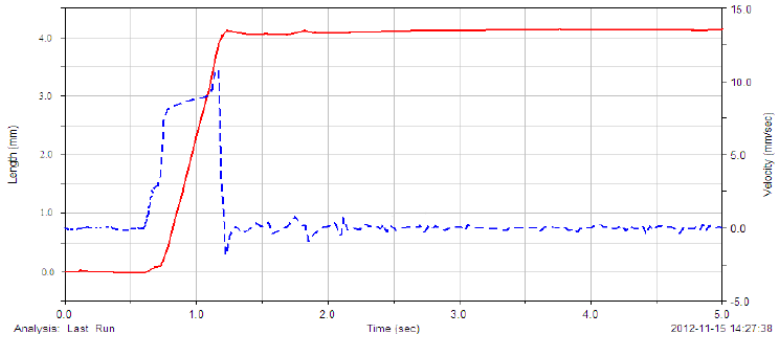

Fig.4.1 Periodic component of the maximum short circuit current is 500A

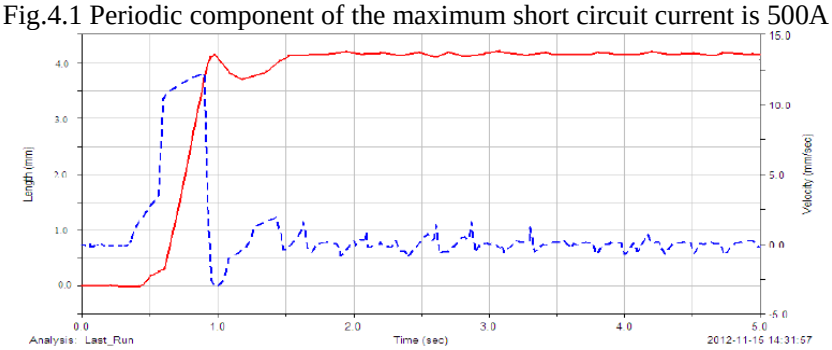

Fig.4.2 Periodic component of the maximum short circuit current is 750A

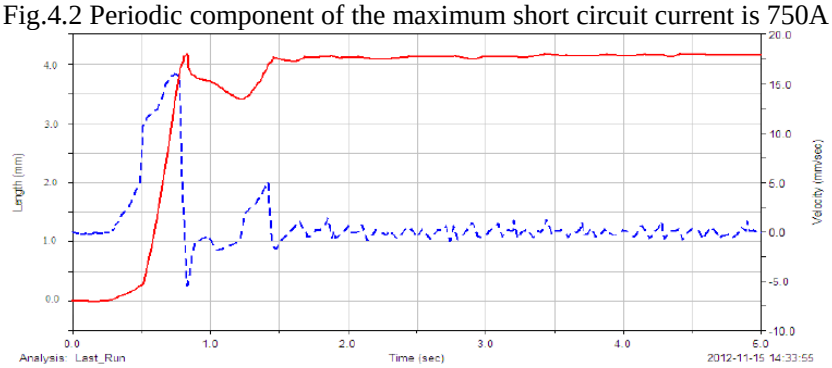

Fig.4.3 Periodic component of the maximum short circuit current is 1000A

Fig.4 dynamic characteristic accounting electromagnetic force

Simulation results can be seen from Figure 4, in different short-circuit current, breaking contacts will have different speeds. When the cyclical component of the short-circuit current is 500A peak, the moving contacts touch time is 0.6s, static and dynamic contacts completely separate probably 1.2s; when the short-circuit current is 750A peak cyclical component, the moving contacts touch time is 0.4s, static and dynamic contacts completely separate probably 1.0s; when the short-circuit current cyclical component peak is 1000A, the moving contact time of 0.3s, static and dynamic contacts completely separate in about 0.8s. Seen as the current increases, the contact breaking speed will increase, the elapsed time breaking process will become shorter. It can also be seen that when the cyclical component of the short-circuit current is 500A peak, the static and dynamic contact after separation, will be more stable, with only slight quiver, no big rebound.

Conclusions

Miniature circuit breaker has been widely used in the household or in public places. It protects devices and people. Especially the breaking characteristics in short circuit, it decides the reliability of protection in fault. In this paper, model of contacts system is constructed and introduced to ADAMS. The electromagnetic force change and current kinematic are linked, in the case of taking into account the electromagnetic force and the electric repulsion. The results show that: the higher the current is, the greater the contact breaking speed will be; the function of electric repulsion in contact breaking process can’t be ignored.

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