International Journal of Mechanical and Industrial Engineering

Volume 2 | Issue 3 Article 9

January 2013

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Abstract - In this paper, the main function of a circuit breaker is to open up a circuit for a pre-defined time so as to prevent a sudden surge in current that could damage the equipment due to high heat is discussed. The equations of motion derived in this paper can predict the closing, opening of spring type operating mechanism in predefined time as well as be used to compute dynamic response of the moving contact. Using the optimized switch gear mechanism, the atlas of all feasible mechanisms for the spring-actuated controlling system of a circuit breaker has been synthesized.

Keywords - *Circuit breaker, multi body dynamic analysis, switchgear, Switch on/off spring. , FEA, ANSYS.*

I. INTRODUCTION

The dynamic response of circuit breakers can also be analysed using multi-body dynamics. This method is particularly important in analysing the dynamics of complicated mechanisms. Basically, multi-body system is an assemblage of rigid machine members, the members which produce relative motions due to constraints. In multi-body dynamics, Lagrange equation is usually employed to derive a set of second order non-linear differential equations that are subsequently solved by numerical methods. However, the number of differential equations increases exponentially with increasing complexity. Not only does the derivation process become tedious, the computing time also increases significantly when solving these equations numerically.

The spring type operating mechanism for a SF6 gas insulated circuit breaker, mechanism has 2 degrees of freedom (DOF).

When working in open, Close or return modes by fixing a link that adjoins the frame it transforms into single – DOF system. In this manner motion requirements can be achieved and the characteristics of the structure and its resulting complex motions can be analyzed.

Several different classifications of switchgear can be made.

- By the current rating.
- By interrupting rating
- Circuit breakers can open and close on fault currents
- Load-break/Load-make switches can switch normal system load currents
- Isolators may only be operated while the circuit is dead, or the load current is very small.

II. PRINCIPLE OF CIRCUIT BREAKER

In the close operation, as illustrated in Figs. 1 and 2, [7] link 7 is locked by the tripping latch and hence, remains stationary. Link 2 is the follower of the driving cam, and link 6 generates the output motion.

In open operation, a positioning pin prohibits link 2 from rotating counterclockwise. As the tripping latch is turned on, the tripping spring rotates link 6. At the same time, link 7 is rotated clockwise from the effect of the tripping spring. In return operation, the higher spring constant of the tripping spring than that of the returning spring stops link 6 from rotating, while link 2 is rotated clockwise by the returning spring.

This type of circuit breaker is particularly useful in power supply systems where unpredicted situations may arise. In undesirable circumstances, the tripping and closing springs in this circuit breaker, which are constantly in the ready mode, can be manually overridden to perform the sequence 'open-return-close-open-return in an instant. The emphasis here is that it can produce two open operations at any one time, making them safer and more reliable.

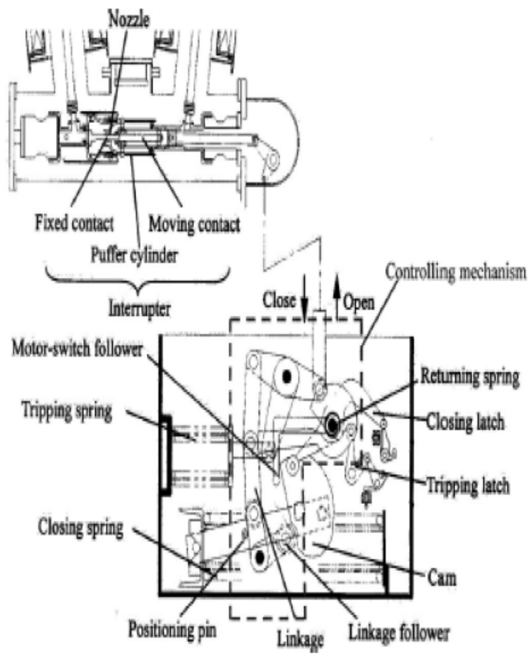

Fig. 1 : Gas insulated circuit breaker

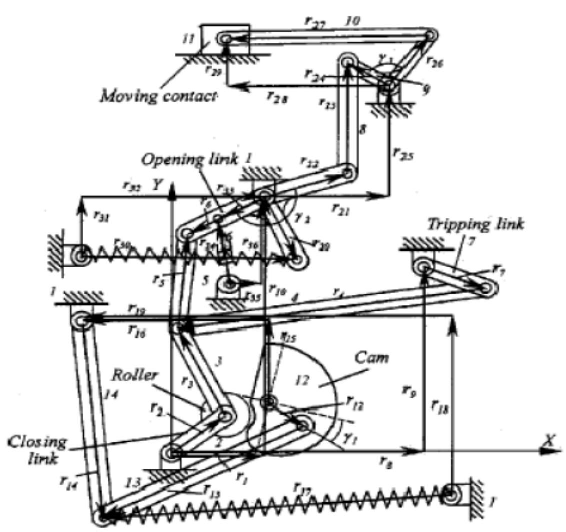

Fig. 2 : Vector loop diagram

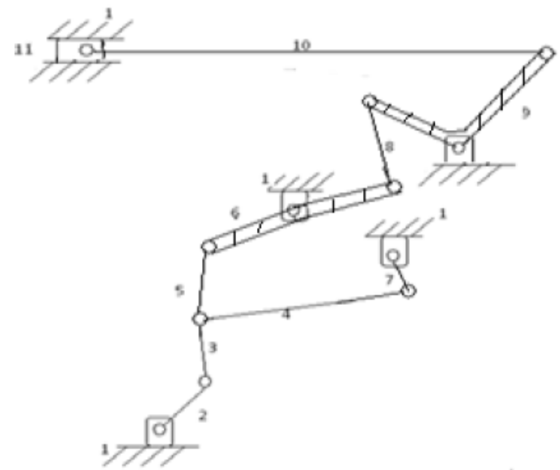

Fig. 3 : Schematic of switch gear mechanism

III. SWITCH GEAR DESIGN

This circuit breaker has the following topological structure characteristics:

1. The controlling mechanism consists of eleven links and fourteen revolute joints, two of which form a multiple joint and the mechanism is thus considered as having two degrees-of -freedom(dof)

2. In each of the three basic operation, by fixing an arbitrary link that adjoins the fixed link, the mechanism is reduced to a ten-member linkage consisting of thirteen revolute joints, two of which form a multiple joint. The mechanism has thus a single dof.

3. The controlling mechanism has a closing link 2.During closing, this acts as the input link which compresses the tripping spring and drives the moving contact of the interrupter to mesh with the fixed contact to form a loop.

4. An opening link 6 exists in the controlling mechanism and acts as the input link during opening. It separates the fixed and moving contacts of the interrupter and opens up the circuit.

5. The returning link 7 in the controlling mechanism acts as the input in the return operation and functions mainly to return the mechanism to the initial position in readiness for closing. The status of the links and springs during the three operations are summarized in Table 1. The controlling mechanism for a circuit breaker has two-dof. In the close, open, and return operations, different links are fixed to achieve the

desired motions, which is analogous to the fixing of different links in the planetary gear train to attain the desired speed ratio [4]

Table 1 Status of switch Gear Mechanism

Oper ation	*Clos ing link*	*Open ing Link*	*Return ing link*	*Clos ing spring*	*Trip ping sprin g*	*Retur ning spring*
Close	Input	Motio n	Fixed	Relea sed	Com p resse d	Fixed
Open	Fixed	Input	Motio n	Fixed	Relea sed	Comp r essed
Retur n	Motio n	Fixed	Input	Motio n	Fixed	Relea sed

IV. KINEMATIC ANALYSIS

For the close operation, spring drives the cam via a link and cam in turn drives the follower, to close up the moving and the fixed contact while compressing the switch of and contact springs. The cam rotates about 1800. The roller follower is followed the cycloid motion, which is being mostly used for high speed applications, the roller follower motion optimized one [7] is considered for the analysis. Hence the input values of follower angular displacements have been applied from this paper as given in the fig-4.

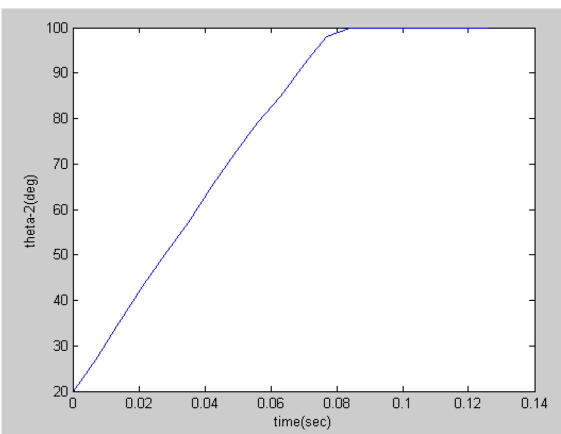

Fig. 4 : Follower angular displacement

As this follower motion is the oscillation type, with the radius equal to its length, the lift (s) of the follower can be found for the maximum rotation of the cam. Angular displacement can also be found as follows using equations extracted from the paper.

Once after knowing the angular rotation of the follower, its angular velocity and angular accelerations can be found by differentiating with respect to the closing time intervals. This follower angular displacement curve (Fig-4) can be suitably fit in to the fourth order equation with the help of MATLAB.

Opening:

Similarly for opening operation, the various link rotation angles can be found by considering the same equations which are used for closing operation of the switch gear mechanism. However the link 2 remains fixed for opening operation.

V. RESULTS & CONCLUSIONS

The initial positions of the circuit breaker's mechanism are obtained through kinematic analysis by considering the system to be initially stationary and the numerical method applied by using MATLAB. The analyzed results for the close and operations are shown in Figs.5 through 6.

The displacement of the moving contact during closing is 0.089 m and the operating time of the circuit breaker is 0.13 sec. The numerical results are comparable with the results shown by the Fu-Chen Chen [8].

The time period of operation is in the order of milli seconds to avoid arcing. This is difficult to observe with a naked eye. The mechanism has been simulated and verified for its operating time [0.08 sec]. Results from Ansys and solid works are comparable. The deviation in the results is due to the absence of dampers and torsion spring. The maximum velocity of the moving contact is 4 m/s and the obtained values are within the limit. Multi body systems have conventionally been modeled as rigid body systems with superimposed elastic effects of one or more components. A major limitation of these methods is that nonlinear large-deformation, finite strain effects, or nonlinear material cannot be incorporated completely into model. The finite element (FE) method is used for modeling a multi body system. It has the following advantages:

The finite element mesh automatically represents the geometry while the large deformation/rotation effects are built into the finite element formulation.

- Inertial effects are greatly simplified by the consistent mass formulation or even point mass representations. Interconnection of parts via joints is greatly simplified by considering the finite motions at the two nodes forming the joint element.

- The parameterization of the finite rotation has been well documented in the literature and can be easily incorporated into the joint element formulations thereby enabling complete simulation of a multi body system.

- Geometric properties of switch gear mechanism elements are width of the links 2 through 9 is 12 mm and the thickness is 4 mm. The link 10 is considered as the hollow circular rod having outside diameter 33.7 mm and inside diameter 26.65 mm. The moving contact mass is 0.5 kg.

The tripping-off spring dimensions are as follows: Spring wire diameter: 5 mm; Outside coil diameter : 47 mm; Inside coil diameter : 37 mm; Fee length : 200 mm; Number of active coils: 12;

Load at mounting length on the spring : 244 N;

Load at working length on the spring : 700 N;

Stiffness of the spring : 10.54 N/mm;

Material : IS 4454 with black coated finish.

The switch gear mechanism elements are considered as beams , the connections between them as revolute pairs and the moving contact as a concentrated mass , the whole system as multi body system has been analyzed by using ANSYS software. The Finite element model of the switch gear mechanism is shown in figure.7.

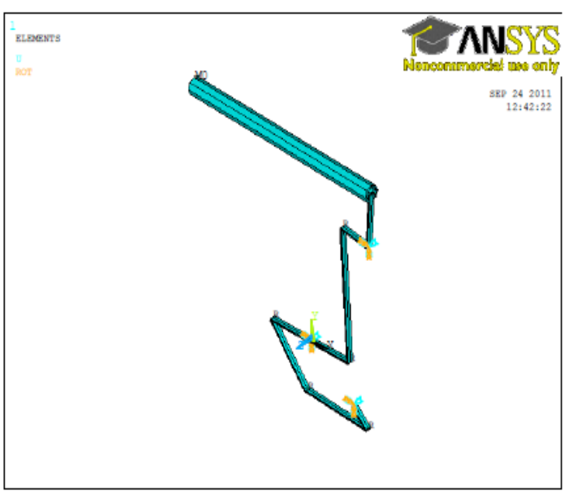

Fig. 5 : ANSYS of Switch Gear

Table 2 Comparision of Results

		SOLID WORKS RESULTS	ANSYS RESULTS
LINK 6	ANGULAR DISPLACEMENT	67 deg	51 deg
	ANGULAR VELOCITY	1802 deg/s	1547deg/s
	ANGULAR DISPLACEMENT	6000 deg/s^2	4000 deg/s^2
LINK 8	ANGULAR DISPLACEMENT	29 deg	6.3 deg
	ANGULAR VELOCITY	538 deg/s	630 deg/s
	ANGULAR ACCELERATION	0.68*10^5 deg/s^2	2.86*10^5 deg/s^2
LINK 9	ANGULAR DISPLACEMENT	79 deg	80 deg
	ANGULAR VELOCITY	1203 deg/s	2292 deg/s
	ANGULAR ACCELERATION	0.6*105 deg/s^2	1.08*10^5 deg/s^2
LINK 11	LINEAR DISPLACEMENT	75 mm	71 mm
	LINEAR VELOCITY	2.2 m/s	3.6 m/s
	LINEAR ACCELERATION	139.6 m/s^2	490 m/s^2

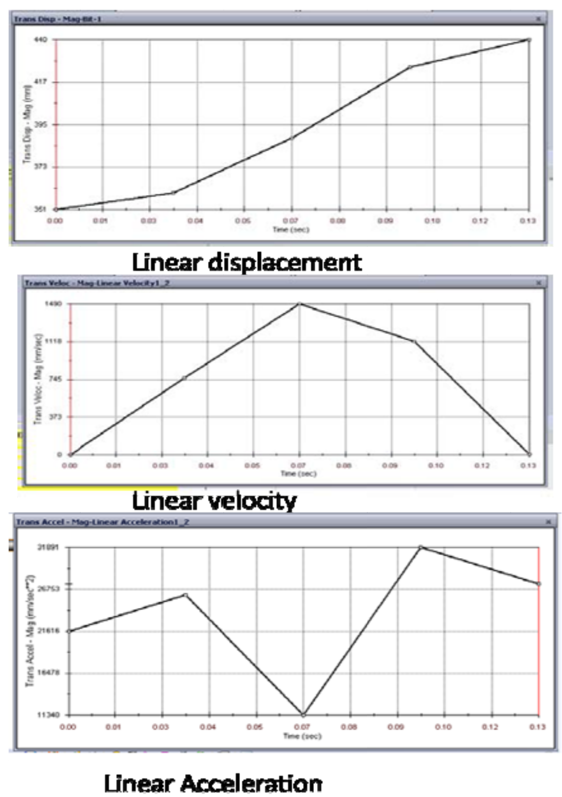

Fig. 6 : Link 11 Closing Operations

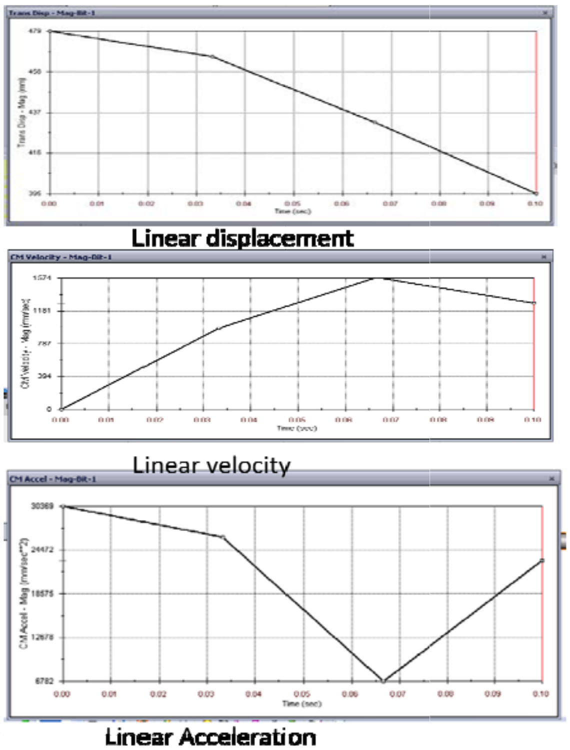

Fig. 7 : Open operation of Link 11

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous reviewers for their comments which were very helpful in improving the quality and presentation of this paper.

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