Improvement of Reliability of Closing Latch in Spring Type Operating Mechanism of High Voltage Circuit Breakers

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***Abstract*- Occasionally closing operation failures occurred when a spring type operating mechanism was used to operate a high voltage circuit breaker with higher loads. This kind of failures is a high risk for circuit breakers. The objective of this paper is to propose a concept of reset time difference of a trip-open unit and to improve the reliability of closing operation of a high voltage circuit breaker with a spring type operating mechanism based on the reset time difference. In a spring type operating mechanism, there is a big latch and a small latch in a trip-open latch unit. In a close operation of a high voltage circuit breaker driven by a spring type operating mechanism, there is a time lag between the big latch and the small latch when they reach their final latched positions. And we definite the time lag as the reset time difference (T_R). The experimental results showed that the reliability of closing operation can be guaranteed with T_R was higher than 10ms. And T_R increased with an increase of a preload of the big latch spring. And the bounces of the small latch were the most significant factor to cause a closing operation failure. An improvement from the point of view of time reset difference (T_R) enhanced the reliability of closing operation of a high voltage circuit breaker.**

I. INTRODUCTION

The reliability of high voltage circuit breakers is essential to the fulfillment of power network failure elimination. The purpose of a circuit breaker operating mechanism is straightforward enough. It is simply to close and open the contacts as required[1]. Most of the characteristics involved in the process of the opening, closing and maintaining the contacts closed can be quite demanding [2]. It is reported that the 70%~90% of high voltage circuit breaker failures are attributed to mechanical causes according to previous investigations [3-5]. Thus, an important conclusions from the reliability studies of high voltage power circuit breakers are a need for further improve the mechanical reliability [3-5].

A commonly used mechanism for high voltage circuit breaker is a spring type operating mechanism. The highest risk for a spring type mechanism driven circuit breaker is a failure mode 'Does not open or close on command' [4]. In opening operation, an opening spring should supply a suitable opening speed and a total travel distance of contacts for a successful interruption of circuit breaker. However, a closing operation is more complex and more prone to cause the mechanism failure than the opening operation. It is found that occasionally closing operation failure occurred when a high voltage spring type operating mechanism was used to operate a high voltage circuit breaker with a high load. In order to improve the reliability of circuit breakers, Thuries et al. [6] have developed a new architecture in the low voltage auxiliary circuits of its circuit breakers. Other approach adopted as efficient maintenance method to extend circuit breaker's lifetime and the mean time to next failure [7-11]. However, as a key component for a successful closing operation of high voltage circuit breakers, a trip unit of the spring operation mechanism has not been improved to enhance the reliability of a closing operation. Once the trip latch unit is unable to hold a high voltage circuit breaker in its close position, it will lead to a failure of closing operation.

The objective of this paper is to propose a concept of reset time difference to improve the reliability of a closing operation of a high voltage circuit breaker with a spring type operating mechanism.

II. EXPERIMENTAL SETUP

A LW-36 126kV SF_6 circuit breaker was used as a test circuit breaker in our experiments. This circuit breaker was operated by a spring type operating mechanism, as shown in Fig. 1. The spring mechanism consists of a closing spring, a closing cam, an opening spring, a damper, a charging motor, various toggles and linkages, and a trip unit. Here a closing spring charged by a electric motor provides a simple and reliable source of energy required to drive the circuit breaker's closing operating sequence. A closing signal releases a charged closing spring's latch, which allows the closing spring to drive the circuit breaker into the closed and latched position. However, the operating mechanism does not stop when it first reaches the closed position immediately. It continues to move over the closed position because of inertia. Once the residual energy dissipates, the operation mechanism returns back to the closing position because of a preload of the opening spring. At the same time, the opening spring is fully charged and a trip-open latch unit is engaged to

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maintain the circuit breaker in a closed position. The detail of the trip-open latch unit is shown in Fig. 2. There is a big latch and a small latch in a closing latch unit. When the operating mechanism first reaches the closed position, the big latch begins to rotate clockwise by a spring of big latch. Then the small latch rotates clockwise by a spring of small latch and reaches its closing position. And the closing position is maintained by the trip-open unit when the operating mechanism returns back.

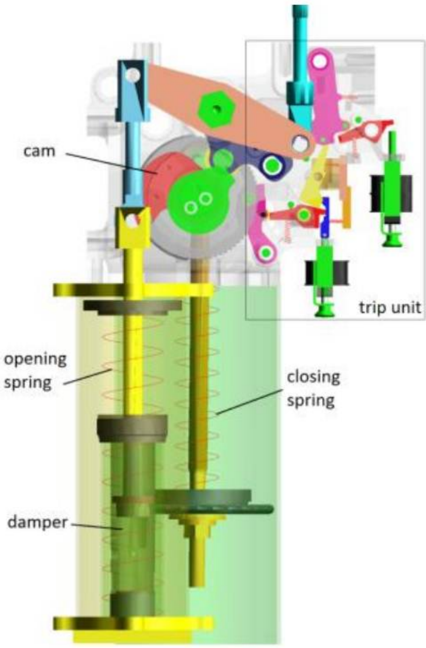


Fig.1. Simulation model of a spring type mechanism

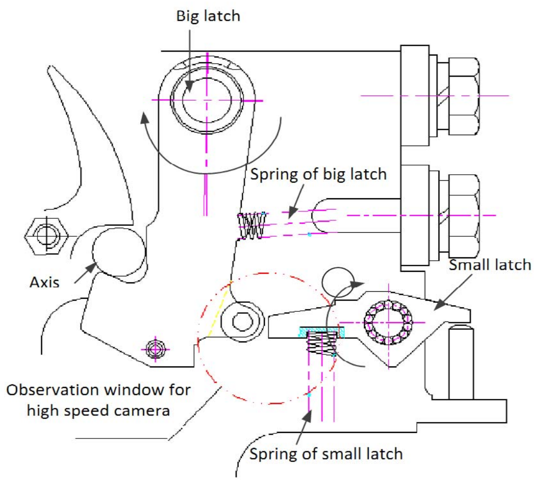
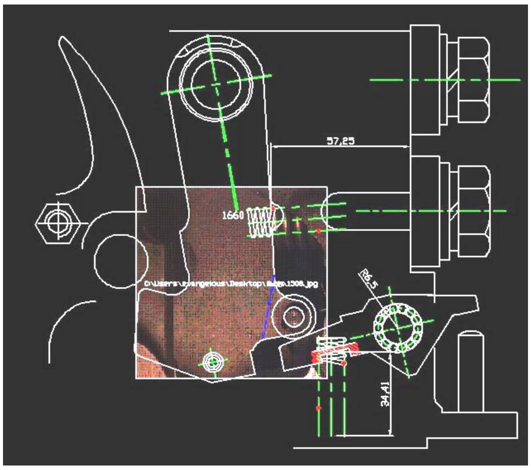
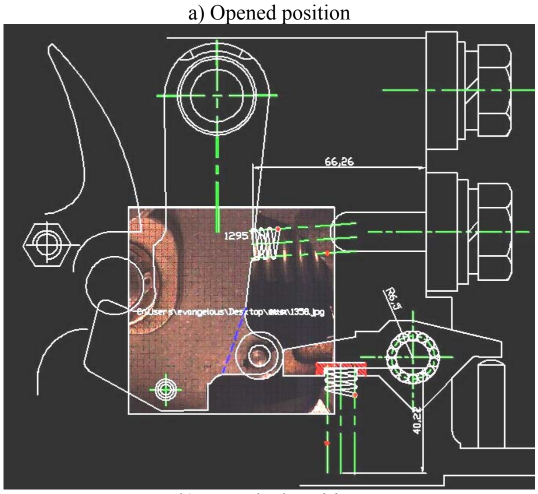


Fig.2. A trip-open latch unit of the spring type mechanism

In order to observe the movements of the trip-open unit in a closing operation, we opened an observation window on an envelope of the spring type operating mechanism without distorting its operation function. And a high-speed camera (Phantom V10) was used to record the movement of the big and small latches during the closing operation. The exposure time of high-speed camera is 197μs, and its recording speed is 4000 frames/s. Figure 3 shows two typical positions of the trip-open unit including an open position, and a close position. And we matched these photographs with the drawings of the trip-open latch unit with an AutoCAD software. Therefore, the actual position of the trip-open latch unit can be measured. We measured the position of a big latch spring and a small latch spring, which directly represented a motion information of the big and small latches, respectively. Therefore, the displacement characteristics of the big latch and the small latch can be obtained by using a series of photographs at a specified time interval.



a) Opened position

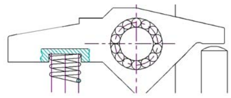
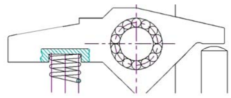
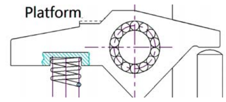
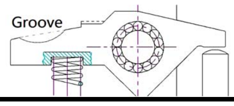


b) Latched position

Fig.3. Typical positions of the trip-open unit

A total travel of the test circuit breaker is 120mm and the average closing speed is 2.75m/s. During the experiments， we compared four different kinds of structures of the trip-open latch unit, as showed in Table I. The four different structures are as follows： a trip-open latch unit used in a commercial spring operating mechanism; Type II is the one that the preload of big latch spring increased by twice; Type III is the one that a platform of the small latch decreased; And type IV is the one that has a groove on the platform of the small latch. Each trip-open latch unit was tested three times.

Table I. FOUR DIFFERENT TRIP-OPEN LATCH UNIT

Type	Preload of the spring of big latch（N）	Height of small latch platform（mm）	Diameter of the groove in small latch（mm）	The shape of small latch
I	350	3.00	0	
II	700	3.00	0	
III	700	2.00	0	
IV	700	2.00	10.89	

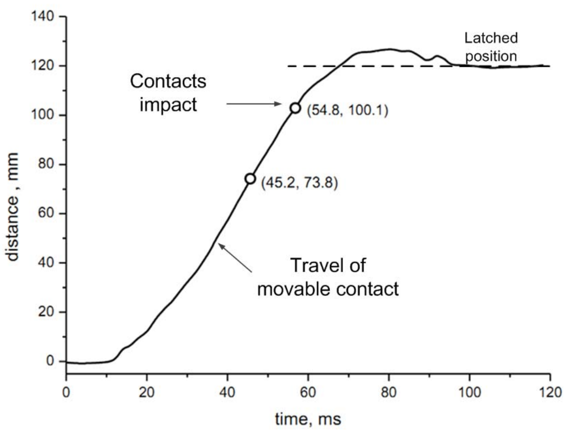


Fig.4. A closing curve of the test 126kV SF_6 circuit breaker with average closing velocity of 2.75m/s

III. RESULTS

A. Definition of reset time difference

A moving characteristic of the big and small latches in one closing operation was shown in Fig. 5. It was found that each latch had a stable latched position in a closing operation of the circuit breaker. The latched positions of the two latches also determined the final closed position of the circuit breaker. The small latch reached its final latched position at t_A, while the big latch moved more slowly and the time of reaching latched position is t_B. There is a time lag between the big latch and the small latch when they reach their latched positions. And we proposed a definition of reset time difference (T_R) is (t_B - t_A). If the reset time difference (T_R) is below zero, the small latch will not reach its latched position. And it is impossible to hold the load of circuit breaker, which will lead to a closing failure. Otherwise, if the reset time difference (T_R) is above zero, the small latch reaches its latched position waiting for the big latch and circuit breaker reaches their stable close position. In such way, the trip-open latch unit moves in a right sequence and maintains a closed position of the circuit breaker successfully.

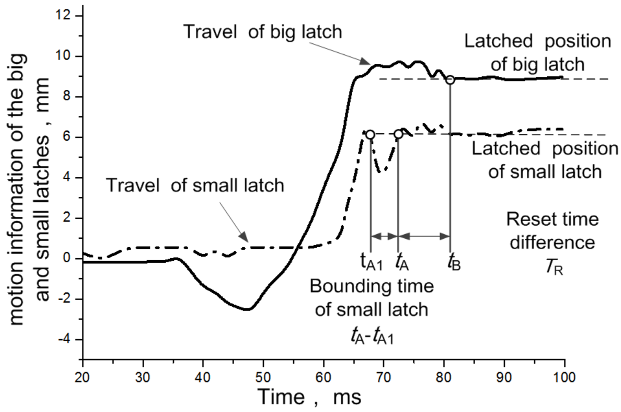


Fig.5. Schematic diagram of reset time of big and small latches.

B. The bounces of small latch

There are several bounces that the small latch reaches its latched position, such as the interval from t_{A1} to t_A as shown in Fig. 5. If the instant of the big latch reaches its latched position (t_B) is in the interval of the bouncing period of the small latch (t_A-t_{A1}), it also leads a closing operation failure. Thus, the bouncing phenomenon of the small latch is also a major influence on the reliability of closing operation.

C. Comparison with the difference trip-open latch unit

It was shown in Fig. 6 that the comparison of the reset time difference (T_R) among the four trip-open latch units. By increasing the preload of the big latch spring twice, the big latch moves faster and the small latch reaches its latched position firstly (t_{A1}) earlier. And a larger preload of the big latch spring prevents the big latch returning back. The time of its final latched position (t_B) is longer. thus, the reset time difference (T_R) of type II, III, and IV were increased from 10.47ms to about 12ms. And type III had a greatest variation of reset time difference than other types trip-open latch unit. Fig. 7 shows a comparison of the bouncing time of small latch (t_A-t_{A1}) among the four trip-open latch units. It is shown that both the Type III and type IV with a 2mm platform had about 2ms bouncing time of small latch (t_A-t_{A1}), which is much lower than type I (3.73ms) and type II (5.73ms). Based on a high and stable reset time difference and low bouncing time of small latch, we considered the type IV latch unit can improve the reliability of the closing operation of high voltage circuit breaker with a spring type operated mechanism

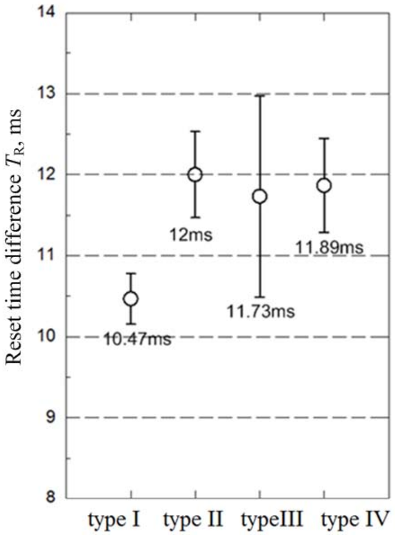


Fig.6. Comparison of reset time difference T_R among four type trip-open latch units

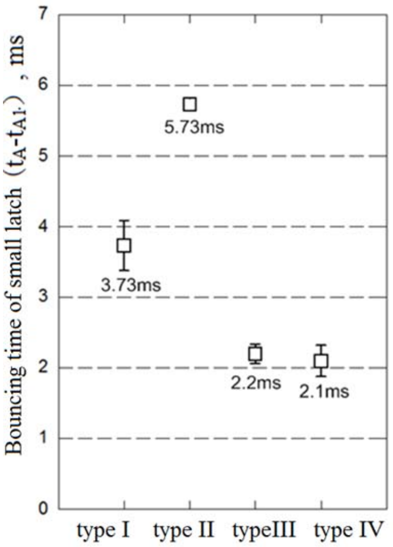


Fig.7. Comparison of bouncing time of small latch among four type trip-open latch units

IV. CONCLUSION

In order to improve the reliability of closing operation in spring driven circuit breakers, a concept of reset time difference is proposed to evaluate the reliability of closing operation of a circuit breaker with a spring type operating mechanism. The definition of the reset time difference is a time lag between the big latch and the small latch when they reach the latched position. The experimental results showed that the reset time difference in a 126kV SF_6 circuit breaker is larger than 10ms. And the reset time difference increased up to 12ms with an increase by twice preloads of the big latch spring. And the bouncing time of small latch were the most significant factor to cause a closing operation failure. It can be reduced by changing the shape of small latch. An improvement of trip-open latch unit from the point of view of time reset difference enhanced the reliability of the closing operation of the 126kV circuit breaker, which has a high and stable reset time difference and low bouncing time of small latch.

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