RESEARCH ON ADJUSTMENT IN OPENING VELOCITY CHARACTERISTIC OF CIRCUIT BREAKER WITH ON-OFF VALVES PCM CONTROL

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ABSTRACT

For the unchangable opening velocity characteristic of the high-voltage circuit breaker,it is proposed in this thesis to add electromagnetic on-off valves in hydraulic mechanism of circuit breaker, and apply PCM signal as input signal in flow rate control to adjust the opening velocity characteristic of high voltage circuit breaker. And the moving equation of circuit breaker with on-off valves PCM control was gotten in this paper .This method can meet the need of grade adjustment in opening velocity of high voltage intelligent operation circuit breaker.

KEY WORDS circuit breaker; intelligent operation; hydraulic mechanism; electromagnetic on-off valve; PCM control

FOREWORD

High voltage circuit breaker is the most important protection and control apparatus in power system. With the applying of computer controller in control of high voltage circuit breaker, intelligent circuit breaker has been researched recently. Intelligent operation of high voltage circuit breaker was proposed in thesis[1],it was defined as the self-adapting controlling transfer of the moving contact(s) from one position to adjacent position.As first step ,the implement of intelligent operation can be done through grade adjustment with most interrupting operation happened below heavy rated current load and few operation in fault current condition.The principle of velocity grade adjustment through on-off valves in high voltage circuit breaker with hydraulic mechanism is proposed.

1 The process and operating principle of high voltage circuit breaker with hydraulic mechanism

The mechanism analyzed in this paper is the differential hydraulic mechanism which was always held in high pressure ,as fig.1 shows. The moving piston is coupled with circuit breaker drive mechanism and the moving

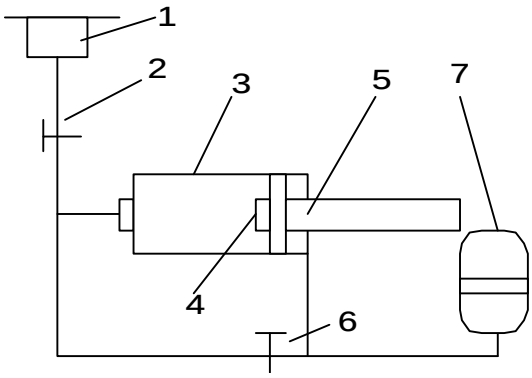

Fig.1 The principle figure of hydraulic mechanism

1-oil tank ;2-open valve ;3-hydraulic cylinder ; 4-buffer head ;5- piston ;6-close valve ;7- accumulator

parts of the chamber. The hydraulic mechanism in fig.1 is in close position with open valve 2 in close position and close valve 6 in open position. The two sides of piston are under high pressure ,because of differential force effect ,breaker is in the close position. During open operation the open valve 2 is to be opened, close valve 6 is to be closed. The high pressure hydraulic oil in the left side of piston 5 flow into low pressure oil tank 1 through open valve 2.At the same time hydraulic piston began to move for the high pressure oil on right side of piston which drive circuit breaker to open. In the end buffer head 4 moved into buffer room and the opening velocity decreased [2] .

Figure 2 shows the no-load opening velocity characteristic of circuit breaker.At the beginning of open operation, velocity increased at great acceleration. Following the increasing of velocity,the gas pressure in puffer chamber increased ,so does the resisting force,the acceleration of open velocity begin to decreased,but the opening velocity of circuit breaker is still increasing.Then the buffer stage of the open operation comes,the open velocity declines because of buffer effect .The *V-l* characteristic shows two rapid velocity declines for

the two grade buffer structure of hydraulic mechanism of model circuit breaker. [3] .

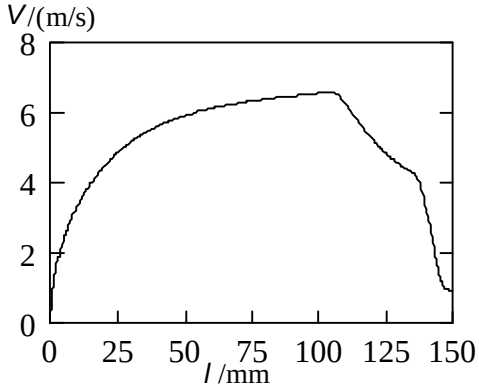

Fig.2 The no-load opening velocity characteristic of circuit breaker

With the mass of moving system being naturalized to piston ,the open moving equation of circuit breaker as follows:

$$P_1A_1 - P_2A_2 = M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + F_1 + kF_2 \qquad (1)$$

Here:P_1 is high pressure on the hydraulic piston;A_1 is the effect area of the high pressure side of hydraulic piston;P_2 is the low pressure on hydraulic piston; A_2 is the effect area of low pressure side of hydraulic piston; M is the general mass of moving system naturalized to hydraulic piston; x is distance of moving piston; t is time of performance; B is viscosity coefficient; F_1 is force of puffer chamber; F_2 is hydraulic buffer force.

2 The analysis of velocity adjustment of hydraulic mechanism

The throttle adjustment method is taken into action with the energy of hydraulic mechanism of circuit breaker supplied by accumulator during the design of circuit breaker. The output speed of circuit breaker was regulated by adjusting the drain oil aperture. The change of diameter of drain oil aperture will cause the change of output flow. The adjusting principle of adjustment of diameter of drain oil aperture as **Fig.**3:

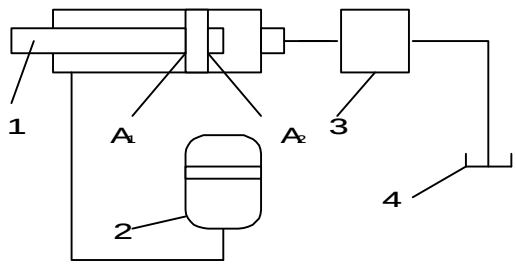

Fig.3 The principle of flow adjustment of velocity control

1-hydraulic piston 2-accumulator 3-throttle adjusting module 4-oil tank

Overlook the conduit pressure loss the pressure P_2 is the sum of atmosphere pressure of oil tank 4 and drain oil aperture pressure loss ΔP_2.In which ΔP_2 is:

$$\Delta P_2 = \lambda\frac{\rho}{2}V_1^2 \qquad (2)$$

There λ is pressure loss coefficient of drain oil aperture which is function of area of throttle ρ is density of hydraulic oil V_1 is oil velocity of drain oil aperture.

It can be deduced that the pressure P_2 is related with press loss coefficient of throttle λ .So the adjustment of piston moving characteristic can be done through the change of λ .The adjusting principle is :The change of diameter of drain oil aperture will cause the change of piston speed as other condition is certain.

3 The selection of control valve in circuit breaker velocity adjustment

There are electro-hydraulic servo-valve, electro-hydraulic proportional valve and electromagnetic on-off valve in hydraulic control which can meet the requirement of grade speed adjustment in intelligent operation of circuit breaker.

As a control valve ,electro-hydaulic servo-valve can adjust the flow direction and flow constantly according with the polarity and quantity of input electric signal which has advantage of good linearity ,small dead zone and high response speed.

For the control characteristic of electro-hydraulic proportional valve is similar with servo-valve ,but the control precision of servo-valve is much better.

The electromagnetic on-off valve adjusts the flow with input on-off control signal. Although on-off valves only have two control states, the combined use of several on-off valve in hydraulic system can output more control states.

As a control equipment in hydraulic mechanism of circuit breaker, the selection of hydraulic valves affect the performance of circuit breaker greatly. So it is very important that the selection of valves should be accorded with the trait of hydraulic mechanism of circuit breaker.

The action of hydraulic mechanism in circuit breaker is different from general hydraulic mechanism for its high speed,short operating time and high pressure. So the valve used in hydraulic mechanism of circuit breaker should have high work pressure and high response speed to meet the

system requirement.

Through the comparison of three valve, for the grade speed adjusting of circuit breaker, electero-magnetic on-off valve is taken as a suitable control component for its high response speed, simple control method .

The static flow equation of on-off valve as follows:

$$Q£½C_d wx\sqrt{\frac{2}{r}\Delta P} \tag{3}$$

In which Q is the flow of on-off valve; C_d is the flow coefficient of valve;w is the area gradient of valve; *x* is the moving distance of valve core;ñ is the gravity of hydraulic oil;ÄP is the pressure on the valve.

4 The PCM Control strategy of on-off valve adjustment

PCM(pulse code modulation) is widely used in fiber communication and satcom as a digital coding method. With PCM the sample analog signal is quantified and coded in turn for digital transmitting after sampling. Recently the PCM method was to be used in position and velocity control system of pneumatic and hydraulic system, and better effect was gotten by combining with advanced control method(such as fuzzy control).[5]

Several on-off valves being combined in hydraulic system could take PCM method into action. So when the control schedule is decided,the range of controlled output should be quantified ,the number of on-off valves can be certain in turn.The binary control signal controls the states of on-off valves when controller works.

The grade speed adjustment can be realized with flow change in several position between max and min PCM flow state,which can be gotten with the combined use of several on-off valves as **Fig**4 and **Tab**1 shows(in Fig5 two on-off valves used as special example)

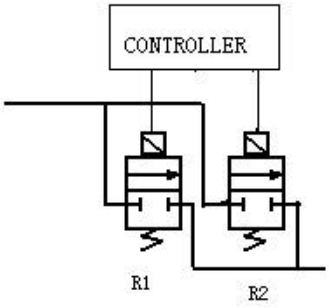

Fig 4 Principle of hydraulic PCM method

Tab.1 The PCM adjusting states table of on-off valve

States of output of PCM control module	States of valve R1	States of valve R2
1	1	1
2	1	0
3	0	1
4	0	0

If in open state the flow of on-off valve R1 and R2 is Q_1 and Q_2, the flow *Q* of PCM control module with combined use of two on-off valves in Fig 5 will be:

$$Q = k_1Q_1 + k_2Q_2 \tag{4}$$

In which *Q* is the general flow of PCM control module; k_1,k_2 is the states coefficient of on-off valves R1,R2 k_1,k_2 is 1 for open state and 0 for close state.

With the use of PCM on-off control module in the hydraulic mechanism of circuit breaker , the moving equation of open operation of circuit breaker will be

$$P_1A_1 - P_{21}A_2 = M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + F_1 + kF_2 \tag{5}$$

in which:$P_{21}$is the low pressure on hydraulic piston with on-off valves module used;the other parameter has the same meaning as in equation 1 .

The flow equation of control module is:

$$Q = k_1C_d w_1x_1\sqrt{\frac{2}{r}\Delta P_c} + k_2C_d w_2x_2\sqrt{\frac{2}{r}\Delta P_c} \tag{6}$$

In which : k_1 ,k_2 is state parameter of on-off valves,the value is 1 for open state 0 for close state; C_d,w,x has the same meaning as in equation 3 ;ÄPc is the pressure on control module,ÄP=P_{21}-ÄP_1-P_m,P_m is the pressure of oil tank

Because the flow in hydraulic system is constant,the flow of control module and hydraulic piston will be equal:

$$Q = A_2\frac{dx}{dt} \tag{7}$$

From (6)(7) there's

$$P_{21} = \frac{\frac{2}{r}A_2^2\left(\frac{dx}{dt}\right)^2}{\left(k_1C_d w_1x_1 + k_2C_d w_2x_2\right)^2} + \Delta P_1 + P_m \tag{8}$$

From (8) (5),then

$$P_1 A_1 - \left(\frac{\frac{2}{r} A_2^2 \left(\frac{dx}{dt} \right)^2}{\left(k_1 C_d w_1 x_1 + k_2 C_d w_2 x_2 \right)^2} + \Delta P_1 + P_m \right) A_2 = M \frac{d^2 x}{dt^2} + B \frac{dx}{dt} + F_1 + kF_2 \quad (9)$$

The equation (9) is the moving equation of high voltage circuit breaker when control module was taken into action. Change of states coefficient k_1, k_2 will change the moving characteristic of open operation of circuit breaker.

CONCLUSIONS

It is feasible and economical to apply PCM on-off valve control in grade velocity adjusting of hydraulic mechanism to meet the velocity control of intelligent operation of circuit breaker.

The moving equation of open operation of circuit breaker gives the theoretical base for velocity adjusting of high voltage circuit breaker intelligent operation.The equation can be used in a more wide area,with which the open velocity of circuit breaker can be calculated.

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