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Point on Wave Switching of SF6 Circuit Breaker using Real Time Monitoring of Various Parameters.

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Abstract: *Circuit Breaker is an important element of Indian economy in power systems. This paper introduces the real time analysis of coil voltage, Idle time, and SF6 gas pressure for optimizing point on wave switching of SF6 circuit breaker. The circuit breaker is the special device which does all the required switching operations during current carrying condition. It provides protection to transmission equipment in networks. This paper describes that due to variation in SF6 gas pressure, variation in coil voltage Operation of SF6 Circuit Breaker in real time as SF6 gas is used for arc quenching in the Circuit Breaker to get the Point on wave Switching. The paper also describes the Compensation of coil voltage, SF6 Gas Pressure, ideal time used for Point on wave switching method used for Controlled switching of Circuit Breaker. Control switching of circuit breaker gives enhancement of circuit breaker performance, reduction and control of switching transients, improvement of power quality and extension of equipment life.*

Keywords*— Circuit Breaker, Sf6 gas, Controlled Switching, Compensation, switching transients*

I. INTRODUCTION

SF6 Gas plays a important role for operation of breaker. Due to excellent performance of SF6 circuit Breaker, it is used for 11kV upto 1200 kV. SF6 gas has been used as arc quenching and insulating medium for high voltage switchgear systems. Due to superior arc quenching property,SF6 circuit breakers have very short arcing time.SF6 is an alternative to other conventional insulating and quenching media such as e.g. oil, vacuum and air. The use of SF6 gas considerably increases, in some applications, Due to dielectric strength of SF6 gas is 2 to 3 times greater than air, that's why SF6 circuit Breakers can interrupt larger currents.

At the same time SF6 in comparison to oil, vacuum and air reduces the risk of hazard to the environment. An overall evaluation considering all ecological, economic, safety and technological aspects has proven that SF6 gas has good dielectric and arc extinguishing property. The existing SF6 technology in the field of energy transmission and distribution is the result of decades of optimization and contributes essentially to the further development of the economically efficient power distribution. The controlled switching i.e. point on wave switching for circuit breakers is installed with an electronic device that monitors the health of the circuit breaker and takes in the command from the user in order to CLOSE or OPEN the breaker on the point of wave of a reference voltage or current.

II. SF6 CIRCUIT BREAKER

Nowadays SF6 circuit breaker is very popular in different types of circuit breaker because of its excellent Performance Due to Outstanding properties i.e. high dielectric strength, unique arc-quenching ability, excellent thermal stability and good thermal conductivity, SF6 gas circuit breaker use in power applications. SF6 circuit breaker is dependent on the pressure of SF6 gas. Based on the pressure its mechanism requires certain amount time for actuation.

Controlled switching phenomenon is largely based on the angles at which the phases are CLOSE or OPEN. By this we mean that sequence and angles of switching of phases for a specific load is important. In this for capacitive load close switching is done on the voltage peak when the current is zero per phase. New applications are being researched that adapts to different angles dynamically based on the load type. SF6 gas circuit breaker for point on wave switching is largely dependent on parameters such as DC voltage to coil, SF6 pressure, Air Pressure, load type, frequency of the reference phase, in this we take R-Phase as a reference.

III. CONTROLLED SWITCHING

Controlled switching is nothing but switching the load at the optimum point on voltage or current wave so that the transients will be minimum possible.

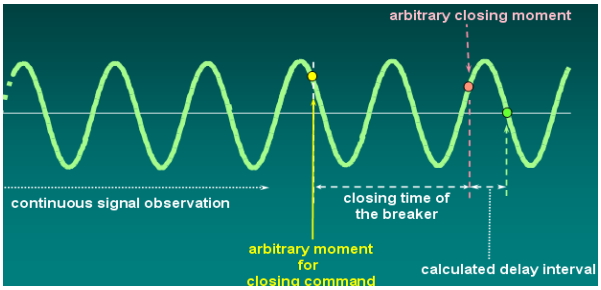

Fig 1 Signal Presentation

With the help of controlled switching Breaker contacts are opened & closed precisely on the targeted point on wave. Controlled switching is a technique that uses an intelligent electronic device, i.e., an intelligent controller, to control the timing of closing and opening of independent pole breakers with respect to the phase angle of an electrical reference voltage or current signal. Controlled switching of HVAC circuit breakers is becoming more widely available for switching shunt capacitors, shunt reactors, transformers, and transmission lines.
Advantages of controlled switching are the reductions of high inrush currents, dangerous switching overvoltage, equipment failures, and maintenance of circuit breakers that are switched quite frequently.

IV. POINT ON WAVE SWITCHING (POWS)

Point on wave switching (POWS) is a method to eliminate harmful transients with time controlled switching operations. Closing or Opening commands to circuit breaker are delayed in such a way that the closing or the Opening of contact will occur at optimum time related to phase angle.

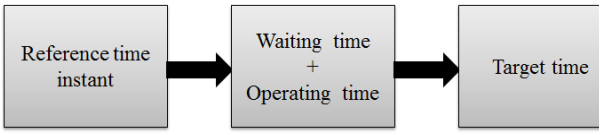

Fig 2 Principle of controlled switching

As shown in above figure reference time i.e. closing and opening commands using point on wave switching some delay is added i.e. waiting time .we get Target time which is combination of waiting time and operating time. With the help of POWS we can increase the performance and life of the circuit breaker.

V. PARAMETERS IN POWS [4]

A. Closing Time
Time from energizing the closing coil until contact touches the circuit breaker.

B. Opening Time
Time from energizing the opening coil until contact separation occurs.

C. Make/Break Time

Time for energizing the closing coil until current starts flowing in the main circuit; Adaptation control adjusts the making instant.

D. Pre-arcing Time
Time from start of current flow in the main circuit until contact touch.
Pre-arcing time = Closing time - Make time

E. Arcing Time
Time from contact separation until contact separation occurs.

F. RDDS
The rate of decrease of dielectric strength, circuit breaker characteristics that describe the rate of fall of the voltage withstand at closing of a circuit breaker.

VI. COMPENSATION IN CONTROL SYSTEM

When the circuit breaker has a variation in its behaviour, with variations in external conditions, corrections for these can be made. Verification of systematic mechanical variations depending upon varying ambient conditions like influence of idle time, change of temperature, change of coil voltage and change of SF6 gas pressure. Variations upon an ambient parameter variation can be compensated for by suitable transducers. The compensation will depend on variations and the actual operating conditions. For frequent operation adaptation control may be good enough to gradually take small variations into account. The system can compensate the circuit breaker's expected operating time for variations in temperature, pressures, SF6 gas pressure and auxiliary voltage supply. In this paper we only discuss SF6 gas pressure, coil voltage ,idle time compensation for real time monitoring of SF6 gas pressure for optimization point on wave switching of SF6 circuit breaker. The following compensations are made in the circuit breaker with the help of these compensations the target for closing and opening operation is achieved.

VII. COMPENSATION OF SF6 GAS PRESSURE VARIATION

SF6 gas is the media for the arc interruption and dielectric strength. In closing operation SF6 gas pressure variation compensation comes into action, at closing time SF6 gas rated pressure is 7 Kg/cm² at C temperature. Closing time is the time from energizing the closing coil until contact touches the circuit breaker. Real time monitoring of SF6 gas pressure is very important for the compensation provided in the system. In table I we provide the SF6 gas pressure compensation with the help of windows based software in this we set breaker close time of 80 msec for each phase (R, Y, B) and SF6 gas pressure is varied. In this the ideal operation is performed when SF6 gas pressure in 7 kg/cm² at C temperature As the temperature increases the SF6 gas pressure should be decreased.

TABLE I : SF6 gas pressure compensation for breaker

Breaker CLOSE time			SF6 (kg/cm2)
R (msec)	Y (msec)	B (msec)	
80	80	80	4.65
80	80	80	6.20
80	80	80	7.40
80	80	80	8.67

VIII. RESULTS OF SF6 GAS COMPENSATION

TABLE II

DC1 Voltage	SF6 Pressure R (kg/cm2)			Expected Time (msec)	Observed Time (msec)	Error
	R	Y	B			
109.49	4.96	4.97	5	0	0.35	0.35
112.8	6.21	6.22	6.25	0	0.95	0.95
109.6	7.41	7.45	7.48	0	-0.45	-0.45
112.7	8.71	8.71	8.66	0	0.85	0.85

IX. COMPENSATION OF COIL VOLTAGE VARIATION

During circuit breaker commissioning for R, Y and B phases. Closing time and opening time are according to standard values of coil voltage and air pressure from the circuit breaker's specification. They will vary with line frequency only. If any of these 3 parameter changes, the corresponding waiting time is compensated in actual mechanical time. Following graph shows the closing time coil voltage variation for one pole with in accuracy of 1.0 mSec.

TABLE 3 : Closing time Vs Voltage

Sr No.	Coil Voltage (VDC)	Closing time (ms)
1	156	86
2	169	84
3	195	81
4	208	80
5	221	78.5
6	234	78
7	260	77.8

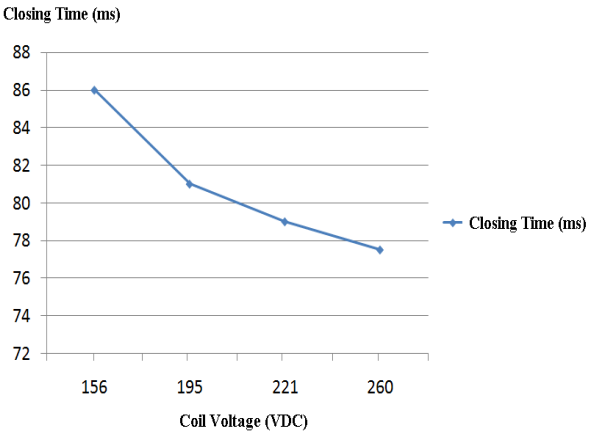

Fig. 3 Closing time Vs Voltage Graph

Following graph shows the opening time coil voltage variation for one pole with in accuracy of 1.0 mSec

Table 4
Tripping time Vs Voltage

Sr No.	Coil Voltage (VDC)	Tripping time (ms)
1	156	22
2	169	21
3	195	20
4	208	19.7
5	221	19.5
6	234	19.3
7	260	19

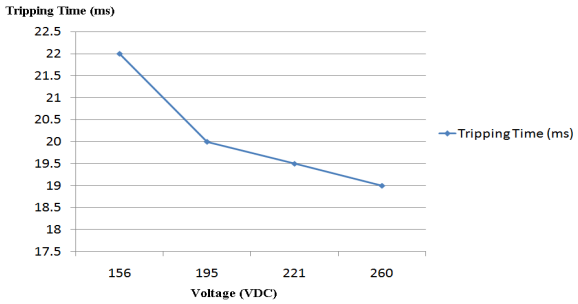

Fig. 4 Tripping time Vs Voltage Graph

X. COMPENSATION OF IDLE TIME

Idle time compensation is used to compensate the predicted operating time of breaker. Idle time compensation is made by taking the delay between operations of the circuit breaker.

If the circuit breaker was idle for a long period then operating time of Circuit breaker adjusts according to supply voltage, ambient temperature, drive mechanism pressure etc. For this compensation calculation of the time between "now" and the last operation was taken, this values continuously increments each seconds but is being reset to zero after the completion of each operation.

XI. COMPENSATION OF AIR PRESSURE VARIATION

The closing and opening time is changed with respect to changes in air pressure. The variation of close and open time with respect to air pressure is compensated in the POWS. The following compensation curves (Figure 9 & 10) are implemented with-in 1.0 ms accuracy. For Calculating opening time at actual Air pressure(Ap) read tripping time(Tp1) at Air pressure(Ap1) and tripping time(Tp2) at Air pressure(Ap2) from HMI entered value then calculate tripping time(Tp) . [6]

XII. CONCLUSION AND FUTURE WORK

In this paper the importance of point on wave switching is explained. This paper presents a method for setting the close and open targets in a controlled switching system based on sf6 gas pressure compensation which is provided with the help of windows based configuration software. The paper also highlights the importance of the SF6 gas pressure compensation as sf6 gas pressure is not in a healthy state, we cannot achieve point on wave switching. To achieve the point on wave switching in circuit breakers there are various types of compensations like idle time compensation, coil voltage compensation, temperature compensation and sf6 gas pressure compensation etc. which are described in this paper. The system automatically adjusts the circuit breaker operation according to the supply voltage, ambient temperature, and drive mechanism pressure.

Furthermore, it was confirmed, in connection with the variations in closing or opening time in response to the operating conditions, that the operating characteristics could be stably compensated over a long period by using the characteristics obtained from the factory test.

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