Development of a 170kV 50kA Capacitorless Gas Circuit Breaker

K. Y. Park*, K. D. Song*, Y. H. Oh*, W. P. Song, J. H. Kang*** and S. W. Park******

Abstract - In modern EHV (Extra High Voltage) class GCBs (Gas Circuit Breakers), the interruption capability for SLF (Short Line Fault) is one of the most important aspects of performance required for GCBs. Up to now, the SLF interruption capability of EHV class GCBs was partially assisted by the adoption of capacitors able to decrease the dV/dt of the TRV (Transient Recovery Voltage), particularly the TRV on the line side.
This paper describes the technique to increase the SLF interruption capability of EHV class GCBs as well as the procedure to develop capacitorless 170kV 50kA GCB.

Keywords: Capacitorless, dV/dt, SLF(Short Line Fault), RRRV(Rate of Rise of Recovery Voltage), FLIC(Fluid in Cell)

1. Background

Recently, the 170kV 50kA GCB used for 154kV transmission systems occupies the largest portion of the domestic EHV class GCB market. The rated breaking current of 170kV GCBs in Korea is primarily 50kA. The main feature of this type of GCB is single-break with capacitors between the contacts.

If the fault current becomes very large, the initial rate of rise of the TRV during SLF interruption becomes very high due to the large fault current and surge impedance. As a result, interruption duty becomes very severe.

To overcome such an undesirable situation, a resistor or capacitor is installed between the contacts. The role of the resistor or capacitor is to reduce the initial rate of rise of the TRV. In domestic cases, capacitors are installed between the contacts for 170kV 50kA GCBs. Usually numerous small ceramic capacitors are connected in a parallel series. Up to now, it has been widely known and accepted that installation of capacitors is necessary for the mitigation of SLF interruption duty.

However, if the successful development of GCBs that can interrupt the SLF current without the capacitors between the contacts can be made, then many problems caused by the capacitors can be overcome. The GCB without capacitors can eliminate the ferroresonance with measuring transformer, induced voltage from the line. Moreover, the cost for the ceramic capacitors, the Teflon tubes used for the installation of capacitors can be cut down. The possibility of dielectric breakdown between the contacts mainly due to the dielectric breakdown in capacitors can also be reduced considerably. And finally, the space for the capacitors inside the GCB tank can be saved. Therefore, the development of a capacitorless GCB is very desirable to strengthen the competitiveness of the GCB.

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2. Relationship Between the Parallel Capacitance and SLF Interruption Capability

2.1 SLF Interruption Capability of GCB

In case of SLF, the magnitude of the line side TRV is expressed by (2.1) and $RRRV_L$(Rate of Rise of Recovery Voltage) can be expressed by (2.2) [1,2].

$$V_L = \sqrt{2}\omega Z_L I\left(t - Z_L C_P + Z_L C_P \exp\left(-\frac{t}{Z_L C_P}\right)\right) \tag{2.1}$$

$$RRRV_L = \sqrt{2}\omega Z_L I\left(1 - \exp\left(-\frac{t}{Z_L C_P}\right)\right) \tag{2.2}$$

where V_L[V] is the magnitude of TRV, $\omega = 2\pi f$, f is power frequency (60Hz), Cp[F] is the value of the parallel capacitance (the total capacitance of the capacitors between the contacts), $Z_L[\Omega]$ is the surge impedance of the line and I is the rms value of the interruption current.

Fig. 2.1 shows the line side TRV waveform calculated from (2.1) with respect to the values of capacitance. As shown in the figure, the value of capacitance affects the slope of the TRV waveform significantly.

The critical RRRV ($RRRV_C$) of the GCB obtained from the experiment can be expressed as follows [3]:

$$RRRV_C = k \cdot P^{\alpha}(dI/dt)^{-\beta} \tag{2.3}$$

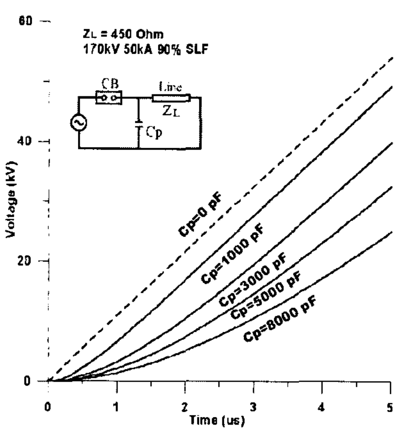

Fig. 2.1 Effects of the capacitance values on the slope of the TRV waveform.

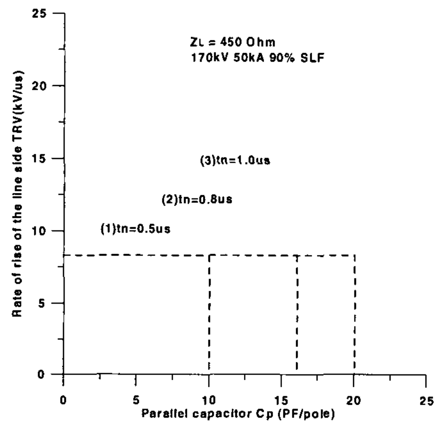

Fig. 2.2 Effect of capacitance value on the rate of rise of the line side TRV.

where P is the pressure in the puffer chamber at current-zero, dI/dt is the slope of the interruption current at current-zero, and k, α and β are the constants to be determined from the tests influenced by the shape of the interrupter, material of nozzle and contact, interruption conditions and so on.

Fig. 2.2 shows the relationship between the RRRV and the capacitance for the different values of t_n (initial average RRRV). As shown in the figure, RRRV decreases as t_n becomes smaller.

Here, t_n indicates the up to the minute time used in determining the average slope of the TRV. In [1], the value of 1.0 μs is used. However, the duration time of post-arc current is usually about 1.0 μs [4,5] and the peak value of post-arc current occurs at the time of 0.5 μs. Accordingly, t_n has been set as 0.5 μs in this paper.

3. Method to Improve the SLF Interruption Capability

3.1 Assessment of SLF Interruption Performance for Existing 170kV 50kA GCBs

To examine the interruption capability of existing 170kV 50kA GCBs, the capacitors were removed and a pressure sensor was attached to the piston wall. Fig. 3.1 shows the pressure measurement system and the structure of the 170kV 50kA GCB interrupter.

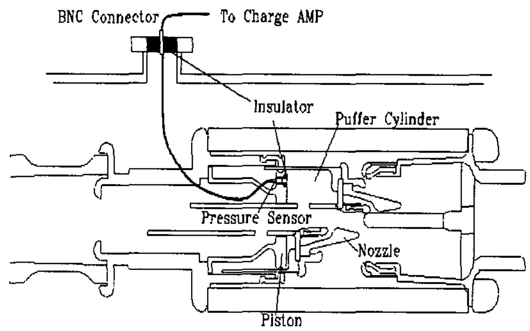

Fig. 3.1 Pressure measurement system and the 170kV 50kA GCB interrupter.

Fig. 3.2 shows the experimental results of interruption capability for the case of 90% SLF. The critical RRRV is proportional to the pressure rise in the puffer chamber with the order of 2.27. The value α = 2.27 is more or less lower than 2.68 presented in [6].

3.2 Improvement of SLF Interruption Performance by Increasing the Pressure Rise

From Fig. 2.2 and Fig. 3.2, the following facts can be deduced for the existing 170kV 50kA GCB with the capacitor of 695pF per phase.

1) In Fig. 2.2, the line side RRRV is approximately 8.6kV/μs for the capacitance of 695pF, and 10.8kV/μs for the capacitance of 0 if curve (1) is chosen. The difference of the line side RRRV is 2.2kV/μs .

2) Therefore, to interrupt the line side 10.8kV/μs RRRV successfully without the capacitors, RRRVc should be increased.

3) In the SLF 90% test for the 170kV 50kA GCB, dI/dt at current-zero is fixed as 24A/μs. Therefore, the only way to improve the SLF interruption performance is to increase the pressure rise in the puffer chamber at current-zero.

4) From Fig. 3.2, the relationship between RRRVc and pres-

sure rise in the puffer chamber at current-zero is as follows.

$$RRRV_C = kP^{2.27} \quad (3.1)$$

5) To increase the interruption capability from RRRVc= 8.6kV/μs to RRRVc=10.8kV/μs, the required pressure rise in the puffer chamber at current-zero is calculated from the following equations.

$$8.6 = kP_1^{2.27}$$

(existing interruption performance) (3.2)

$$10.8 = kP_2^{2.27}$$

(required interruption performance) (3.3)

From (3.2) and (3.3), the following is obtained.

$$P_2 = 1.1\ P_1 \quad (3.4)$$

Therefore, if the pressure rise in the puffer chamber at current-zero increases by 10%, the required SLF interruption capability can be obtained without the capacitors.

6) The increase of pressure rise in the puffer chamber at current-zero could be achieved by modifying the shape of the interrupter and/or by increasing the velocity of the moving contact.

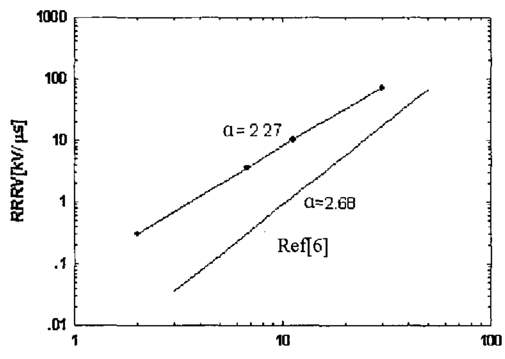

Fig. 3.2 Relationship between the critical RRRV and the pressure rise in the puffer chamber. (170kV 50kA SLF 90%, dI/dt=24A/μs)

4. Prediction of SLF Interruption Capability by Simulation

Fig. 4.1 shows the maximum pressure and pressure at current-zero in the puffer chamber with respect to the arcing time obtained from the hot gas analysis. Fig. 4.2 shows the calculated critical RRRV with respect to the arcing time. To calculate the critical RRRV, the FLIC (Fluid in Cell) method [7] was implemented. Because of the relatively short computation time and the easiness of use, the developed program based on the FLIC method is useful in the analysis of the SLF interruption performance. Fig. 4.2 indicates that the critical RRRV was improved slightly, however not enough to obtain the sufficient arc window and RRRV.

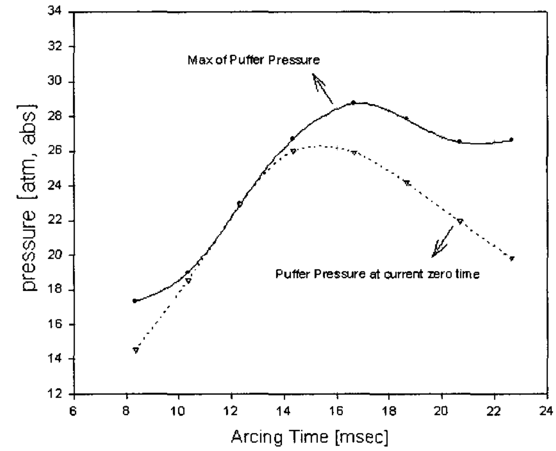

Fig. 4.1 Maximum pressure and pressure at current-zero in the puffer chamber with respect to arcing time (calculated).

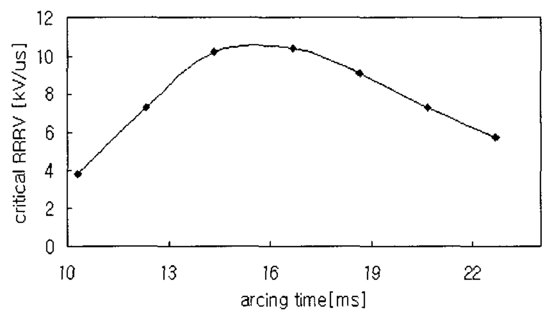

Fig. 4.2 Critical RRRV with respect to arcing time (calculated).

5. Conclusion

(1) A capacitorless 170kV 50kA single-break GCB was developed for the first time in Korea.

(2) Using the interruption tests of existing 170kV 50kA GCBs, the equation for SLF interruption performance was derived.

(3) SLF interruption performance was increased by increasing the pressure rise in the puffer chamber at current-zero.

(4) The increase of pressure rise in the puffer chamber at current-zero could be achieved by modifying the shape of the interrupter and/or by increasing the velocity of the moving contact.

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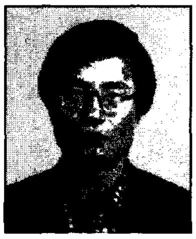

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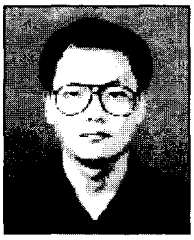

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