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Influence of Model of Circuit-breaker on Very Fast Transient Over-voltage

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Abstract

Based on a power station, two transient models of circuit-breaker is employed and the very fast transient over-voltage in 550kVGIS is calculated and simulated in the consideration of two different models of circuit-breaker, applying the Electro-Magnetic Transient Program in this paper. The impact of varied models on the values and the frequencies of VFTO in the GIS is intensively focused. It is indicated that the two models of circuit breaker have different effects on the peak voltage of VFTO for different nodes. Under the two operation modes, the deviations of the most voltage spectrum frequency are 5.8% and 0 at circuit breaker. Comparing to the results of the two operation modes, the deviation of operating DS21 are higher than that of operating DS22 because of the changing current flow.

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Keywords: circuit-breaker, distributed parameter, VFTO disconnector switch

1. Introduction

The very fast transient over-voltage is unique over-voltage in the GIS due to the operation of disconnector. In the system of the EHV and the UHV, the GIS apparatus are easily endangered by very fast transient over-voltage.

Recent years, great progress has been made in simulation, measurement, and suppression of VFTO, which improve the insulation performance of GIS in China. But UHV GIS and other crucial electrical devices cannot be made by domestic manufacture. It not only heightens the voltage of original devices, but also needs to limit the overvoltage to a reasonable level. With the development of UHV GIS in China, there still exist many works to be done thoroughly for the further study of VFTO characteristics.
In the past, the double fracture circuit-breaker is always taken as lumped capacitor; however the stray capacitance due to the complex structure is neglected. On this condition, the degradation of electrical equipments in breaker is not studied. In the paper, the models of the circuit-breaker with double breaks are regarded as distributed parameter for researching the damage of components in circuit breaker. And based on a power station, the VFTO in the GIS is modeled under the condition of difference models of circuit breaker, and the scope of application about the two models is provided. Computer simulations have been done using EMTP.

2. The Model of Gis Appartus

A one line diagram of the 550kV GIS is shown in figure.1.

![Figure 1. Single line of diagram of the 550kV GIS](image)

The mode of connection of 3/2 is used in the station. This station has two bus (M1 and M2) with charged state and two outgoing feeder lines from the substation. One outline is connected with inverter station for AC-DC conversion, and another is connected with filter for absorbing the harmonic current and limiting the harmonic voltage in the side of AC.

**Model of circuit-breaker**

The detail inner structure of double fracture circuit-breaker is shown in Fig.2. In this diagram, there are two main contacts and one auxiliary contact, two shunted capacitors (C1=700pF and C2=700pF) and one closing resistance (R=1500Ω) is shown.

![Figure 2. The structure of the circuit-breaker](image)

Customarily the double fracture circuit-breaker is always taken as lumped parameter model and the stray capacitance due to the complex structure is neglected. The equivalent model is displayed in Fig.3. The lumped parameter model of circuit is constituted of the lumped capacitor (C=350pF) and closing resistance (R=1500Ω).

![Figure 3. The lumped parameter model of the circuit-breaker in the calculation of VFTO](image)

When the double fracture circuit-breaker is replace by the in the lumped parameter model, the effect of VFTO on shunted capacitor and closing resistance is not analyzed. Thus the equivalent model of the circuit-breaker is modeled as the distributed parameter model shown in the Fig.4. In this model, there are
two shunted capacitors (C1=700pF and C2=700pF), closing resistance (R=1500 Ω) and equivalent capacitors of interrupter (C01=150pF and C02=100pF).

![Figure 4. The distributed parameter model of the circuit-breaker](image)

**Models of other components in GIS**

Since the high frequency components range from hundreds of KHz to thousands of MHz is contained predominantly in the spectra of VFTO, the transformer is regarded as lumped inductance and lumped capacitance to ground. The GIS bus acts like transmission line with the transmission time, propagation velocity and surge impedance.

Disconnector is modeled differently under open and closed conditions. When opened, it is modeled as lumped capacitor. When closed, it is replaced by the capacitance to ground. The spark is modeled as an exponentially decaying resistance in series with a small resistance. And the moving contact and fixed contact is modeled the lumped capacitance to earth.

Bushings, earthing switches and surge arrester are modeled as lumped to the ground. In summary the model and the parameter of GIS components except circuit-breaker are shown in Table 1.

**TABLE I. THE MODELS AND THE PARAMETERS OF GIS COMPONENT**

| Component         | equivalent model | Equivalent parameter     |
|-------------------|------------------|--------------------------|
| Transformer       | L=20mH, C=5000pF |                          |
| Earthing switch   | C=240pF          |                          |
| SF6/oil Bushing   | C=320pF          |                          |
| Disconnector (closed) | C=80pF    |                          |
| Disconnector (opened) | C=4.5pF    |                          |
| Disconnector during sparking | r=10^{12} e^{-t/W} Ω, r=0.6*10^{-9} s | R = 0.5 Ω, C = 12 pF |
| GIS busbar        | Z = 62.36, v = 296 m/µs |                          |

3. **The Results of Vfto**

Based on the actual operating mode and the mode connection, the switches of DS21 and DS22 are frequently operated. Thereby the VFTO due to the operation of switches of DS21 and DS22 is analyzed in the paper.

The residual charge of -1.0p.u is used when the disconnector is operated. This matter is severity condition. 1.0p.u=450kV.
Operation of disconnector DS21

The length of overhead line connected with the inverter station and GIS is 110m. The propagation velocity of VFTO is 300m/µs and the surge impedance is 330Ω. The magnitude of VFTO is limited seriously as a result of the long overhead line and the high impedance. Consequently the impact of VFTO refracted from inverter station is negligible. Therefore the overhead line between inverter station and GIS is neglected in the calculation of VFTO along each node in GIS.

When the isolating switch of DS21 is operated, the lumped parameter model and the distributed parameter model are considered. The results of VFTO is shown in the Fig.5 under these conditions.

![Figure 5. The peak value of VFTO when the different models of circuit-breaker are considered (operation of DS21)](image)

According to Fig.5, the VFTO peak values under the condition of the distributed model are bigger than that considered the lumped parameter model. As the series capacitor and the capacitance to ground would be in the circuit when the distributed parameter model of breaker is regarded. And the amplitude of voltage is strengthened by these capacitors.

The results of VFTO in consideration of the lumped parameter model of breaker are taken as the reference voltage. The error of DS21 is less than 1.5%, 8.4% on SF6/oil bushing and 11.4% on CB2. It is obvious that the deviation based on two models of breaker is small. And when the switch of DS21 is operated and the two different models of circuit breaker are taken, the representative waveforms of VFTO on CB2 are shown in Fig.6.

![Waveform of VFTO and Frequency Spectrum](image)

(a)The distributed parameter model of breaker
Currently the VFTO typical experimental wave is not provided in the standard of IEC. When compared with the LIWV, the safety margin of 15% would be taken into account from the view of literature [3]. Accordingly the peak values of VFTO should not exceeded 1347kV corresponded to the LIWV of 1550kV on GIS. According to the Fig.5, the maximum amplitude of VFTO is 1.718p.u on CB2 and is 57.3% times as small as 1347kV.

Operation of disconnector DS22

The length of overhead line connected the filter and GIS is 160m. The propagation velocity of VFTO is 300m/μs and the surge impedance is 330Ω. The magnitude of VFTO is limited seriously due to the long overhead line and the higher impedance. As a result, the impact of VFTO refracted from filter on the GIS is negligible. Thereby the overhead line between inverter station and GIS is neglected in the calculation.

When the isolator of DS22 is operated, the results of VFTO considered the two varied models of circuit breaker are shown in the Fig.7.
0.5%, 0.59% on SF6/oil bushing and 0.26% on CB2. Obviously the deviation is small. And the typical waveforms of VFTO are performed in the Fig.8, when the disconnector of DS22 is operated and two models of circuit-breaker are considered. From Fig.7 and Fig.8, the maximum peak value of VFTO can be got. It is 1.625p.u and is 54.3% times as small as 1347kV.

![The waveform of VFTO](image1)

![The frequency spectrum of VFTO](image2)

(a) The distributed parameter model of breaker

![The waveform of VFTO](image3)

![The frequency spectrum of VFTO](image4)

(b) The lumped parameter model of breaker

Figure 8. The waveforms of VFTO on CB2 when the different models of circuit-breaker are considered (operation of DS22)

4. Conclusion

In this paper the characteristics of VFTO were modeled on the condition that the two different models are used. The results verify that the two models of circuit breaker have different effects on the peak voltage of VFTO for different nodes. Under the two operation modes, the deviations of the most voltage spectrum
frequency are 5.8% and 0 at circuit breaker. Comparing to the results of the two operation modes, the deviation of operating DS21 are higher than that of operating DS22 because of the changing current flow.

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