SUPPRESSION METHODS FOR VERY FAST TRANSIENT OVER-VOLTAGES ON EQUIPMENT OF GIS

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Abstract

Gas Insulated Substations (GIS) have found a broad range of applications in power systems because of their high reliability, easy maintenance, small ground space requirements etc. In a Gas insulated substations, the operation of disconnector switches and circuit breakers can cause Very Fast Transient Overvoltages (VFTOs), which will bring an instantaneous change in voltage with a very short rise time and it is normally followed by oscillation having high frequencies. For designing the insulation level of a substation, it is essential to know the maximum value of VFTO. Fast operating disconnector switches are usually used to reduce time of the breakdown; however, it cannot eliminate fully the effect of the VFTO. Very Fast Transient Overvoltages caused by disconnector switch operation of 1000 kv GIS is simulated and calculated in this paper using MATLAB. The various protection measures on equipment of GIS have been compared and analyzed by adding ferrite rings, opening and closing of resistor, metal oxide arrester and R-C absorber.

Index Terms: *Gas Insulated Substation, Very Fast Transient Overvoltage's, Matlab/Simulink, Disconnector switch.*

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1. INTRODUCTION

Gas Insulated Substations (GIS) have found a broad range of applications in power systems because of their high reliability, easy maintenance, small ground space requirements etc. In a Gas insulated substations Operation of disconnector switches and breakers can cause very fast transient overvoltages (VFTO), tip of which is very steep accompanied with high frequency oscillation [1]. VFTO generated in a GIS should be considered as an important factor in the insulation design. Very Fast Transients overvoltages (VFTO) belong to the highest frequency range of transients in power systems. When Disconnector Switch [DS] is opened or closed in GIS, it will bring an instantaneous change in voltage with a very short rise time in range from 4 to 100 ns, and it is normally followed by oscillation having frequencies in the range of 1 to 50 MHz. For designing a substation it is essential to know the maximum value of VFTO. Several inhabitation methods are available in the literature, which can provide the reference for the protection against VFTO. In this paper a 1000KV GIS is considered to build the simulation model. The equivalent diagram is shown in Figure.3. During the operation of disconnector VFTO'S are observed from 1μs to 3μs (i.e. operating condition of circuit breaker) across potential transformer is showed in figure 4 & 5. Since the main Objective of this article is to inhibit the protection measures to the equipments in GIS a simple simulation model is considered that consists of current transformer (CT) and potential transformer (PT) connected through the disconnectors[2][3]. After the tripping action takes place at the circuit breaker (CB) the VFTO's across CT's a nd PT's are analyzed and the same is done after imparting the opted protection method. The reduction in the VFTO tells that the equipment is safe further after the tripping action.

2. MODELING OF SIMULATION BLOCKS

The proposed simulation model of GIS consists of the following blocks. These blocks modeling and connections are explained in detail as follows:

A. Source Power
B. Source impedance
C. Circuit Breaker
D. Instrumentation Transformer
E. Disconnector switch

Since the whole system is three phase symmetry; single phase circuit can be used to simulate it by doing required modifications.

2.1 Source Voltage

A 1000KV ac source is assumed for simulation model which resembles the considered 1000KV GIS system. The source is modeled from the following equation

$$v_s = \frac{KV}{\sqrt{3}} \cdot \sqrt{2}$$

2.2 Source Impedance

Source impedance assumed for simulation model is calculated using below equation

$$Z = 60 \ln \frac{b}{a} \Omega$$

$$\text{Capacitance } C = \frac{2\pi}{\ln \frac{b}{a}}$$

$$\text{Inductance } L = \frac{\mu \ln \frac{b}{a}}{2\pi} \text{ H}$$

2.3 Circuit Breaker

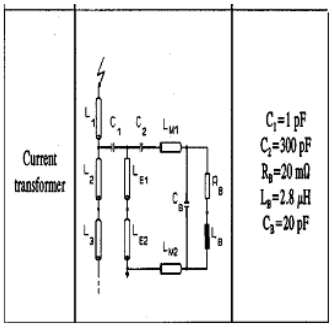
A circuit breaker is connected in series to protect the equipments in GIS from high voltages, which can damage the equipments. Breaker resistance for 1000kv under on state is 0.001 ohms.

2.4 Instrument Transformer

The instrument transformers (CT, PT) used for measuring are connected across the circuit breaker in the assumed model gives the output by which the analysis of VFTO is done. Hence for the assumed GIS system the current and potential transformers are modeled as follows

2.4.1 Current Transformer

The block of current transformer is modeled as interconnection of resistors, inductors and capacitors which can be observed in figure 1



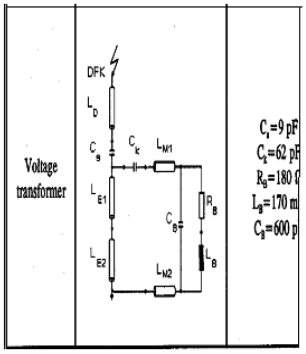
L1, L2, L3: The conductors of the CT inner system
C1, C2: Coupling capacitors
LM1, LM2: Conductors of the Secondary Circuit
CB: Load Capacitance
LE1: Shield Electrode
LE2: Ground Conductor of the Shield Electrode
RB: Load Resistance
LB: Load Inductance

Fig1: Equivalent circuit of current transformer

This current transformer is connected in series to the line after the circuit breaker to measure the current in the line

2.4.2 Potential Transformer

The block of potential transformer is modeled as the interconnection of resistor, inductor and capacitor which can be observed in figure 2



DFK: The Pressure Spring Contact.
CK: Coupling Capacitor
LM1, LM2: Conductors of the Secondary Circuit
LE1: Shield Electrode
LE2: Ground Conductor of the Shield Electrode
RB: Load Resistance
LB: Load Inductance
CB: Load Capacitance
LD: Conductor of the High Voltage Electrode
CS: Field Controlled Capacitance

Fig2: Equivalent circuit of potential transformer

This potential transformer is connected in parallel to line after circuit breaker to measure the voltage in the line.

2.5. Disconnector Switch (DS)

In the simulation model of GIS, disconnector switch is modeled with a capacitor. The closing and opening actions of the disconnector switch is functioned by assigning different values to the capacitor as given below

Disconnector switch in open condition C= 50 pF

Disconnector switch in closed condition C= 88 pF

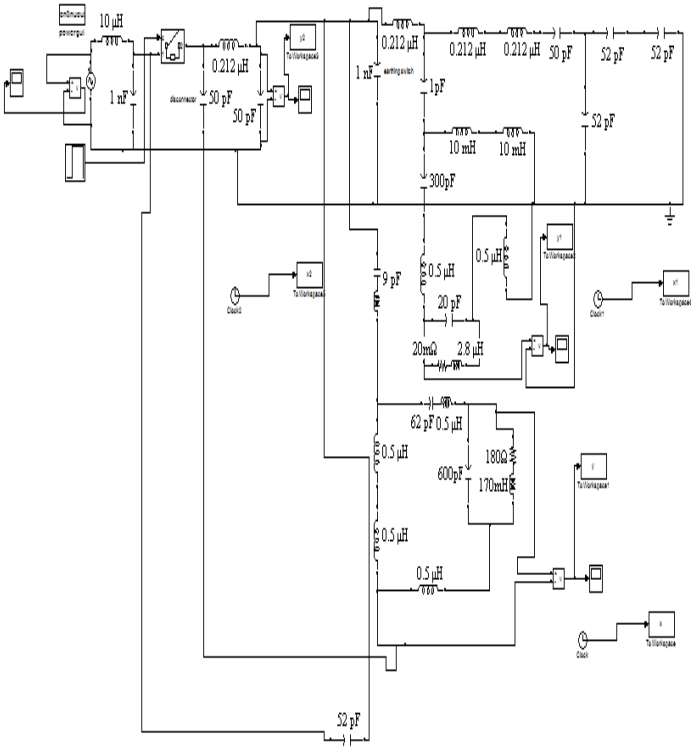


Fig3: Basic simulation diagram of GIS

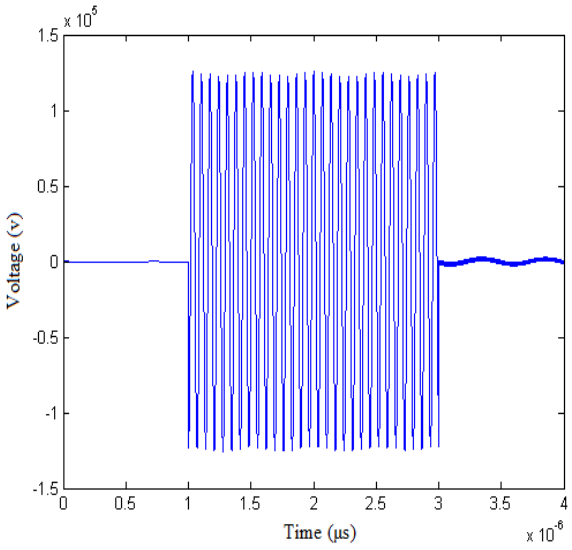


Fig4: Waveform of VFTO across potential transformer

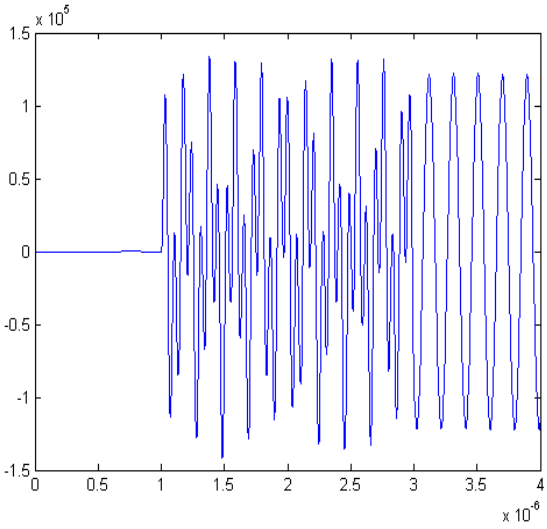


Fig5: Waveform of VFTO across current transformer

3. RESULTS

3.1 Installation Of The Opening And Closing Resistor

The equivalent circuit is modified by connecting 500Ω opening and closing resistor at disconnector switch and waveform is shown in Fig. 6 & 7. The installation of opening and closing resistor has a certain application in order to inhibit the VFTO in GIS [1]. The amplitude of VFTO decreases obviously, and the steepness is limited. However, from a technical and economical point of view, as the compact structure of the GIS, this method brings difficulty in equipment, more seriously it weakens the system reliability. The closing resistor should be equiped with actuator devices in application, which operate frequently, the probability of failure are great. Therefore, this method needs to combine practical considerations.

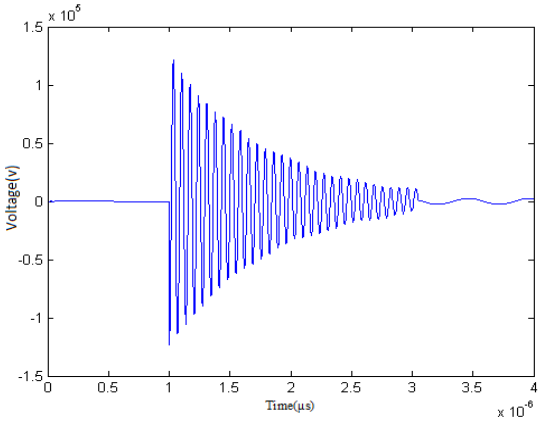


Fig6: VFTO waveform with opening and closing resistor at potential transformer

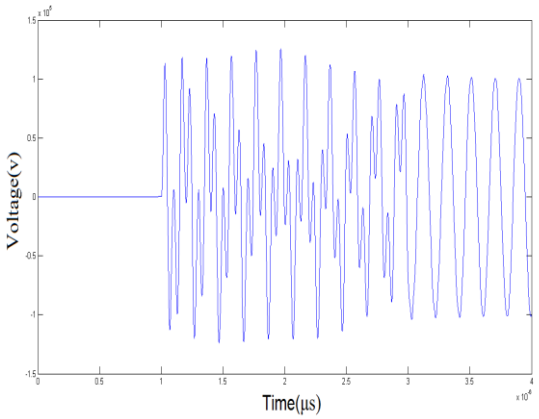


Fig7: VFTO waveform with opening and closing resistor at current transformer

3.2 Installation Of The Metal Oxide Surge Arrester

Metal oxide surge arrester (MOA) is particularly applicable to protection of GIS equipment from voltage surges .The equivalent circuit of 1000kV GIS is considered with metal oxide surge arrester and simulations are carried out. The volt-time characteristic of which is flat. MOA cannot be simulated only by non-linear resistor during passage of high frequency content of VFTO[1]. When MOA is installed at DS, the amplitude decreases is shown Fig 8& 9.However, it is noticed that, MOA only inhibit the amplitude of the VFTO, its steepness basically has no effect, the high frequency components are still present.

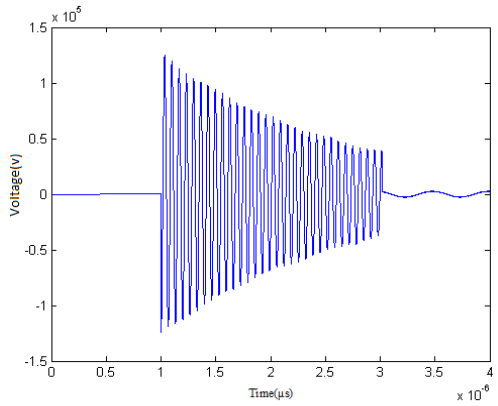


Fig8: VFTO waveform with Metal Oxide Surge Arrester at potential transformer

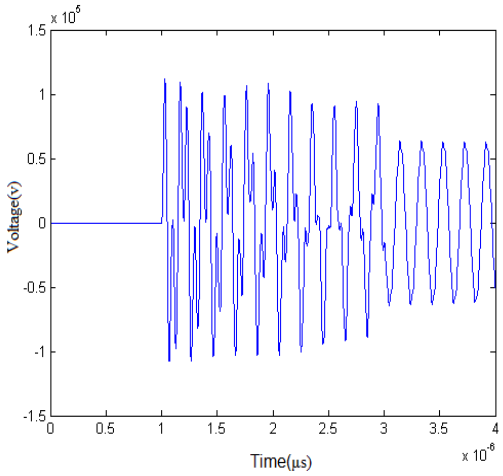


Fig9: VFTO waveform with Metal Oxide Surge Arrester at current transformer

3.3 Installation Of The Ferrite Ring

Ferrite rings are installed at conductor pole of the disconnector switch in order to inhibiting VFTO. The equivalent circuit of 1000kv GIS is considered with equivalent of ferrite ring and simulation results are obtained. Ferrite material has different characteristics of saturation magnetic conductivity, frequency response and loss. These characteristics influence the VFTO suppression effect [4][5] . The suppressing effect on the VFTO could be improved by the high magnetic strength (H), magnetic conductivity (h) and frequency (f) respectively. The effect of reflected wave and the losses are neglected as parallel combination of resistor and inductance the equivalent resistance of the ferrite ring is equal to the surge impedance of GIS bus bar and the equivalent inductance is 0.02 mH, which the inhibition of the VFTO is the largest . The simulations have been carried out after adding ferrite ring equivalent. Fig 10&11.Shows the VFTO waveform and its frequency spectrum. From above results, we find that the saturation characteristic of the ferrite ring material have a great impact on VFTO, However this measure would not increase the complexity of the structure of the GIS and it can play a role in the protection of GIS equipment inside the bus bar.

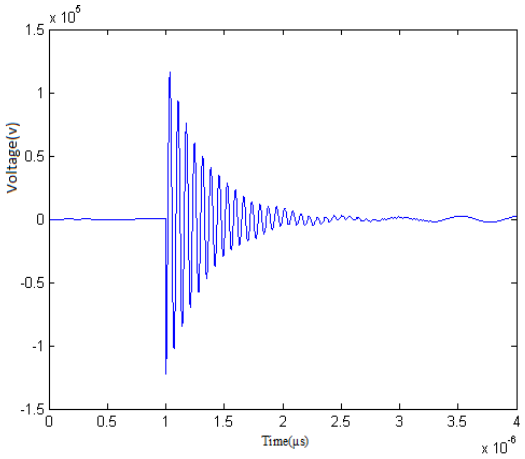


Fig10: VFTO waveform with Ferrite Ring at potential transformer

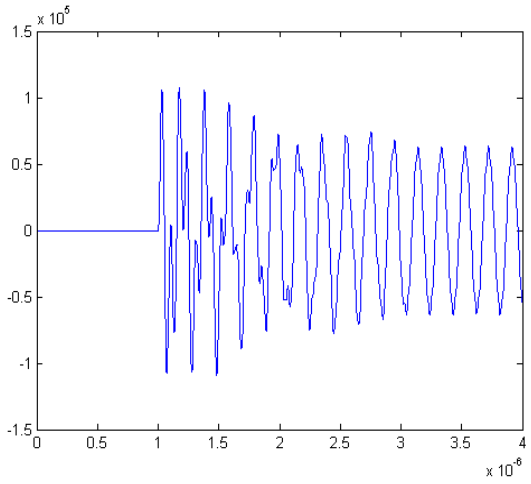


Fig11: VFTO *waveform* with Ferrite Ring at current transformer

3.4 Dinstallation Of RC Filter

The equivalent circuit of 1000kV GIS is considered with equivalent of RC filter and simulations are carried out. The results are shown in the Fig 12 & 13. RC filters have been widely used in vacuum circuit breakers to suppress the over voltages. RC filter is parallel next to disconnector switch. The values chosen for R=100Ω and C =0.2µF, voltage amplitude and steepness drop faster. The main reason of which is that capacitor absorbs the high frequency component and finally energy is consumed resistor.

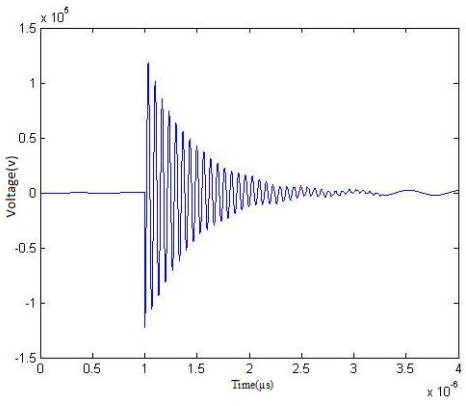


Fig.12 VFTO waveform with RC filter at potential transformer

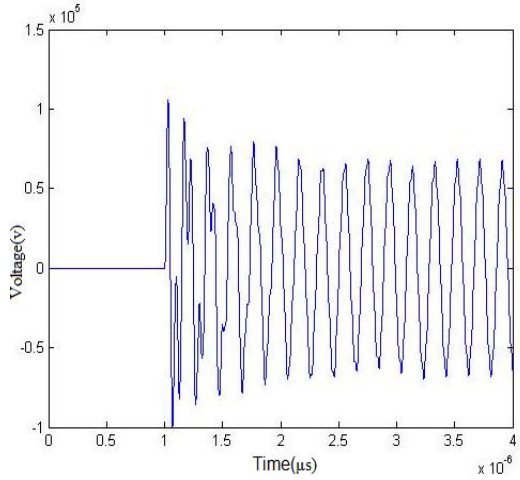


Fig.13 VFTO waveform with RC filter at current transformer

Table.1 Comparison of VFTO's Reduction

Method proposed	At current transformer	At potential transformer
Using opening and closing resistors	66Kv	4Kv
Using metal oxide arrester	96Kv	15Kv
Using ferrite ring	60 Kv	2Kv
Using R-C filter	64Kv	3Kv

CONCLUSIONS

By simulating and calculating various measures adopted to suppress VFTO in GIS, We can draw the following conclusions.

A. The amplitude of VFTO only is suppressed by MOA but its steepness and high frequency oscillations.
B. By installing a opening and closing resistor not only decreases the amplitude but also the steepness of VFTO.
C. The installation of RC filter decreases the amplitude of VFTO as well as steepness of VFTO by absorbing high frequency components energy of VFTO.
D. Installing ferrite rings can decreases the amplitude and saturation characteristics of the ferrite ring material have great impact on VFTO.

FUTURE SCOPE

The effect of VFTO's in the Gas Insulated Substation can analyzed by using PSPICE and ATP-EMTP.

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