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Calculation of Transients at Different Distances in a Single Phase 220KV Gas insulated Substation

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Abstract*:* **--This paper describes the VFTO are usually Transient vervoltages in a gas insulated substation. A few Gas Insulated Substation (GIS) units have been in operation and large number of units are under various stages of installation. These problems include, generation of the overvoltage during Dis-connector operations, line to enclosure faults. The fast transient overvoltages obtained are due to switching operations and with fixed arc resistance and variable arc resistance for different lengths of GIS. The Transients are calculated along with load and it was observed that the transients obtained in 5mts length GIS will affect the system more than that obtained in 10mts length GIS and control of secondary equipment in a Single-phase 220kv GIS. The variable arc resistance is calculated by Toepler's formulae. The equivalent circuits are developed for the components of GIS and voltages are calculated by using the Matlab 7.8 software.**

Keywords—Gas Insulated Substation (GIS), Transient over voltages, Switching operations, single-phase faults, MATLAB 7.8 software and Control circuitry

I. Introduction

Transient over voltages calculated on the basis of fixed arc resistance have presented. It is however, known that the resistance of the spark channels varies with current. At the instant of initiation of arc the resistance is very high[1][2]. As the current in the arc increases the value of resistance starts decreasing until it saturates at very low value. In general, the arc resistance appears to be inversely proportional to some function of current [3].

Several authors a have given arc resistance equations which can be divided into two groups as given below.

1. Inverse integral equation reported by Toepler et.al.[4]
2. Inverse exponential equation reported by Demenik et.al.[4]

These equations were numerically evaluated for a given arc current and then normalized with the experimental arc resistance at = 0.5μs (approximate time of maximum current) of all these equations, one equation has been used for the analysis.

Based on earlier studies in SF6 gas, Toepler's Sparks Law is valid for calculation of variable arc resistance. The variable arc resistance due to Toepler's formulae [4] is calculated as given below.

$$R = \frac{K_T \times l}{q_0 + \int_0^t i(t)\,dt}$$

Where KT = Toepler's Constant
= 0.005 volt .sec /mt for SF6 under uniform
Field conditions
L = Spark Length in meters
qo = Initial Charge
t = Spark Collapse Time in sec

The value of time varying spark resistance R(t) is calculated until it reaches a value of 1 to 3 ohm initial charge qo is an important parameter while considering the non-uniform fields. But the field between the dis-connector contacts is almost uniform. Therefore, initial charge qo is very small and can be neglected [5].

When a circuit breaker operates conducting spark channel is established with time lag of few nanoseconds after the breakdown channels is connected the electrodes [6][7]. During this time only the spark resistance changes from very large value to very small value, For homogeneous fields, this time is given by

$$tz = 13.3 * \frac{KT}{Eo}$$

Where Eo = Breakdown field strength
= $8.6 * 10^6$ volt/mt for SF6
KT = Toepler's constant
= 0.005 volt sec/mt

II. Modelling of 220kv GIS system

For accurate analysis of transients, it is essential to find the VFTO's and circuit parameters. Due to the travelling nature of the transients the modelling of GIS makes use of electrical equivalent circuits composed by lumped elements and especially by distributed parameter lines, surge impedances and travelling times. The simulation depends on the quality of the model of each individual GIS component. In order to achieve reasonable results in GIS structures highly accurate models for each internal equipment and also for components connected to the GIS are necessary.

The dis-connector spark itself has to be taken into account by transient resistance according to the Toepler's equation and subsequent arc resistance of a few ohms. The wave shape of the over voltage surge due to dis-connector switch is affected by all GIS elements. Accordingly, the simulation of transients in GIS assumes an establishment of the models for the Bus, Bushing, Elbow, Transformers, Surge Arresters, Breakers, Spacers, dis-connectors, and Enclosures and so on.

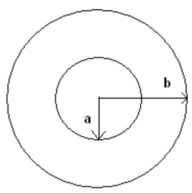
During the current operation of dis-connector switch in a GIS, re-strikes(pre-strikes) occur because of low speed of the dis-connector switch moving contact, hence Very fast Transient Over voltage are developed. These VFTO's are caused by switching operations and single-phase fault

When there is a fault occurs, there is a short circuit in the system. Transients are also produced due to the faults in the system. Due to this VFTO's are caused by switching operation can also lead to secondary breakdown with in GIS. Re-striking surges generated by the dis-connector switches at GIS generally possess extremely high frequencies ranging from several hundred KHz to several MHz. For the development of equivalent circuit low voltage step response measurements of the main GIS components have been made. Using MATLAB of the equivalent models is developed

A. Capacitance calculation

Calculation of Capacitance is done by using the standard formulae given below.

$$C = \frac{2\pi\varepsilon_0\varepsilon_r l}{2.3\times\ln(\frac{b}{a})} \quad \text{\_\_\_\_\_\_ (1)}$$



Where,
$\varepsilon_0 = 8.854 \times 10^{-12}$,
$\varepsilon_r = 1$&

$\varepsilon_r = 4$(for spacers)As they are filled with Alumina filled. Epoxy material:

l = length of the section
b = Outer cylinder radius
a = Inner cylinder radius

B. Calculation of Capacitance due to Spacers

The spacer existed with finite thickness and develops some amount of capacitance in addition with existed capacitance. Spacers are used for supporting the inner conductor with reference to the outer enclosure. They are made with Alumina filled epoxy material whose relative permittivity (εr) is 4. The thickness of the spacer is assumed to be the length of the capacitance for calculation.

C. Inductance calculation

The inductance of the bus duct can be calculated by using the formula [8] given below, where r1, r2, r3, r4, are the radii of the conductors in the order of decreasing magnitude and 'l' is the length of the section.

$$L = 0.001 \times l \times \begin{pmatrix} ln\left(\frac{r1}{r3}\right) + ln\left(\frac{r2}{r1}\right) + ln\left(\frac{r4}{r3}\right) + \\ 2 \times \frac{\left(\frac{r2}{21}\right)^2}{1-\left(\frac{r2}{r1}\right)^2} \times ln\left(\frac{r1}{r2} - 1\right) \end{pmatrix} \quad (2)$$

For estimating these voltages, the equivalent impedance networks for the components like capacitance, and the inductance of the ground wire, grounding grid, spark channel, the resistance of the grounding grid of the spark channel and switch (which follows Toepler's spark law) are required

The variable arc resistance is calculated by using the Toepler's formula. The inductance of the bus bar is found out from the diameters of conductors and enclosure. The bus capacitance is calculated using formula for concentric cylinders. The entire bus length is modelled as distributed pi-network

To simulate the Very Fast Transient over Voltages in GIS, MATLAB is used. The equivalent circuit of GIS is shown in fig2.

Where,
Z1 = Surge Impedance of Gas Insulated Bas duct W.r.to Enclosure Interior surface
Z2 = Surge Impedance of Overhead Transmission Line w.r.to Earth Surface
Z3 = Surge Impedance of Enclosure Exterior Surface with respect to Earth Surface
Cb = Capacitance of the Bushing
C = Capacitance of the Current Transformer

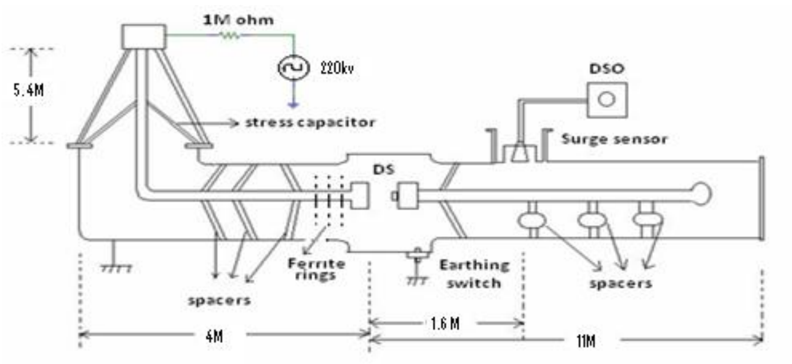


Fig1Modeling diagram of 220kv GIS System

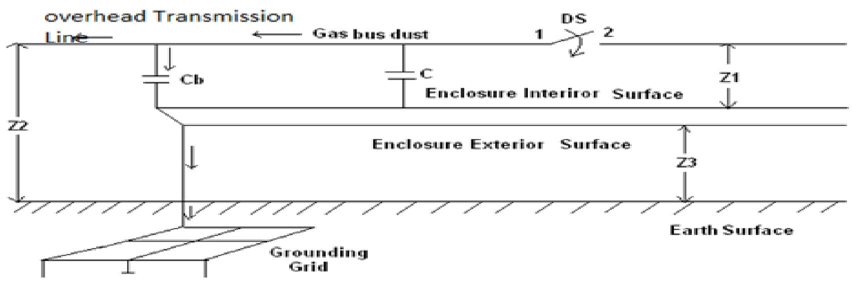


Fig.2 Equivalent circuit of GIS

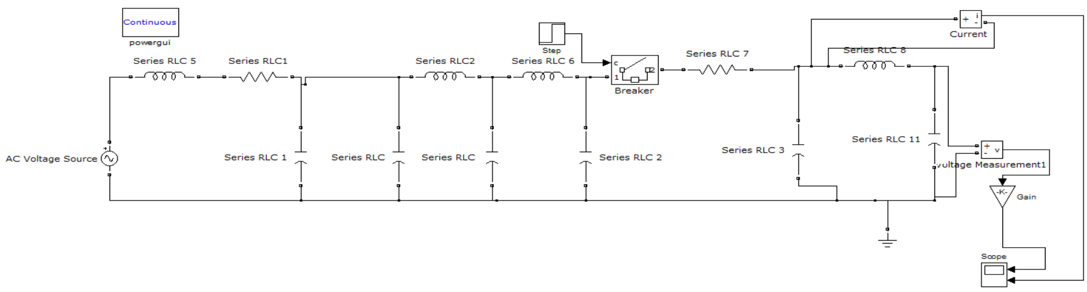


Fig 3 MATLAB Circuit for 5 mts. length in a single -phase 220kv GIS with Variable arc resistance

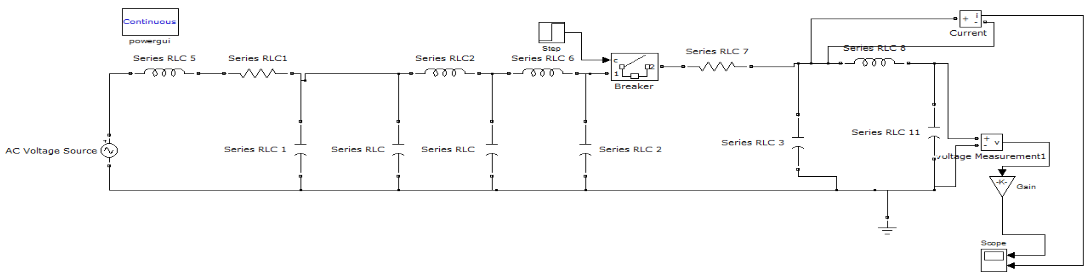


Fig4 MATLAB Circuit for 10 mts. length in a single -phase 220kv GIS with Variable arc resistance

The modelling diagram of 220kv GIS system as in the fig,1 and the following arrangement is assumed for the developing the model and they are phenomena and gas insulated substation concepts can analysis by fig.3 & Fig4

apparatus as disconnected with an earthing switch, three disc type Spencer's , a load bus bar above to 5mts & 10mts long width three post type spacers and a 220kv gas bushing containing stress capacitor.

The 1GHZ surge sensor method in the diagram is located at the distance of 1.6mts from disconnector further, holding the load side bus bar at zero potential, dc voltage was applied from the high voltage dc power supply to the bushing via a 1Mohm resistor and VFTO wave of the closing operations was observed.

III. SINGLE-PHASE EQUIVALENT CIRCUITS FOR 132KV GIS SYSTEM FOR 5MTS & 10MTS LENGTH

The transient due to switching operations for 5mts and 10mts length GIS with variable arc resistance, without load are presented and analysis.

Due to trapped charge some voltage remains on the floating section which can create severe conditions because the first re-strike can occur at the peak of power frequency voltage giving a voltage of 2.0 p.u. On re-strike the voltage on each side will collapse initially zero and hence creating two 1.0pu voltage steps of opposite polarities. In this, it is assumed that re-striking is created at 1.0 p.u. respectively on either side of dis-connector switch (DS). The transients due to closing of the circuit breaker are calculated and maximum voltage obtained with a rise time.

Transients are calculated along with load and it was observed that the transients obtained in 5mts length GIS will affect the system more than that obtained in 10mts length GIS..For different values of voltages on the load side the magnitudes and rise times of 5mts length GIS are Table I. Similarly For different values of voltages on the load side the magnitudes and rise times of 10mts length GIS are Table II.

TABLE I

TRANSIENTS DUE TO SWITCHING OPERATION FOR **5MTS** LENGTH GIS WITH VARIABLE ARC RESISTANCE

Mode of operation	Magnitude of voltage(p.u)	Rise time (Nano sec)
During closing operation	3.36	46
During opening operation	1.38	31
During second re-strike	2.54	14

TABLE II

TRANSIENTS DUE TO SWITCHING OPERATION FOR **10MTS** LENGTH GIS WITH VARIABLE ARC RESISTANCE

Mode of operation	Magnitude of voltage(p.u)	Rise time (Nano sec)
During closing operation	2.38	77
During opening operation	1.06	71
During second re-strike	1.82	50

IV. RESULTS AND DISCUSSION

The transients due to switching operations and line to enclosure faults with fixed arc resistance for different length of GIS are found. Transients are calculated along with load and it was observed that the transients obtained in 5mts length GIS will affect the system more than that obtained in 10mts length GIS. As the distance between the fault point and load increase during fault analysis the magnitudes and rise times of the transients also increases.

. To understand the effect of switching configuration on peak magnitude vs transient currents at different positions, fast transient currents have been estimated for the second switching configuration as shown in below figs. The maximum values of VFTO, the MATLAB7.8 software is used and a simulation is carried out by designing suitable equipment circuits and its models are developed. The main advantages of such models are used to enable the transient analysis in GIS.

Using the equivalent circuit of 5mts length GIS given in Fig 3, transients due to closing operation of the circuit breaker are calculated as given in fig 5. From this graph, the maximum voltage obtained is 3.36 p.u with a rise time of 46ns. The difference between maximum value for Fixed and Variable Arc Resistance is found to be significant.

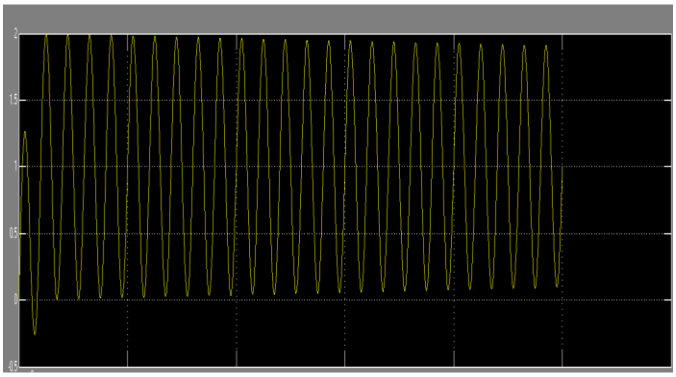


Fig. 5 Transient voltage waveform during closing operation of CB for 5mts GIS, with variable Arc Resistance –phase

By using the above circuit, transients due to opening operation of the circuit breaker are calculated as given in fig 6. From this graph, the maximum voltage obtained is 1.38 p.u with a rise time of 31ns. The difference between maximum value for Fixed and Variable Arc Resistance is found to be significant.

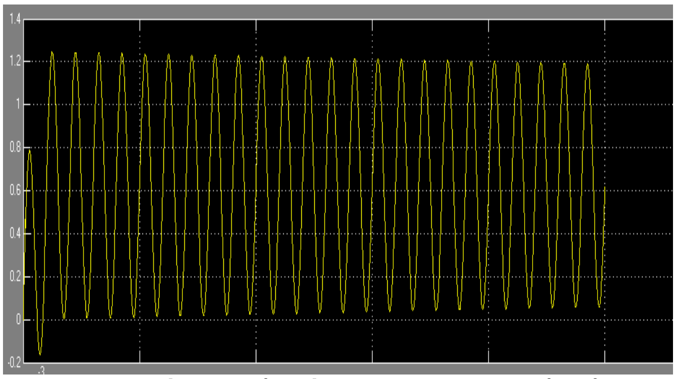


Fig. 6 Transient voltage waveform during Opening operation of CB for 5mts GIS, with variable Arc Resistance

Assuming that there is a second re-strike, another switch is connected in parallel to the circuit breaker for simulation in MATLAB 7.8. Transients are calculated by closing this switch when voltage difference across the contacts of the circuit breaker reaches maximum value. Transients calculated due to second re-strike gives the peak voltage of 2.54 p.u at arise time of 14ns as shown in Fig 7. The magnitudes and rise times of 5mts length GIS are Table I

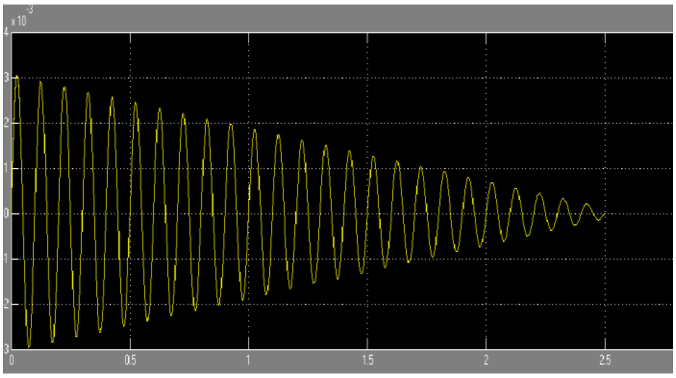


Fig. 7 transient voltage waveform during Second Re-strike for 5mts GIS, with Variable Arc Resistance

. Using the equivalent circuit of 10mts length GIS given in Fig 4, transients due to closing operation of the circuit breaker are calculated as given in fig 8. From this graph, the maximum voltage obtained is 2.38 p.u with a rise time of 77ns. The difference between maximum value for Fixed and Variable Arc Resistance is found to be significant.

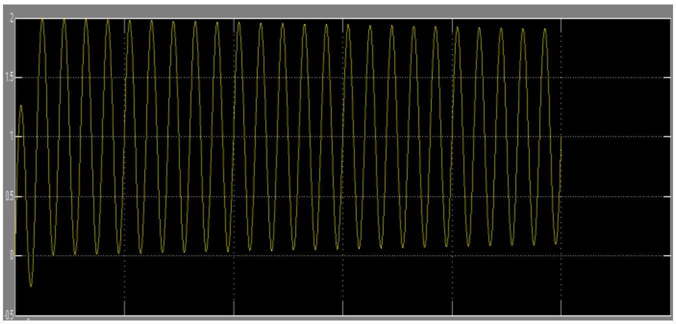


Fig. 8 Transient voltage waveform during closing operation of CB for10mts GIS, with variable Arc Resistance -phase

By using the above circuit, transients due to opening operation of the circuit breaker are calculated as given in fig 9. From this graph, the maximum voltage obtained is 1.06 p.u with a rise time of 71ns. The difference between maximum value for Fixed and Variable Arc Resistance is found to be significant.

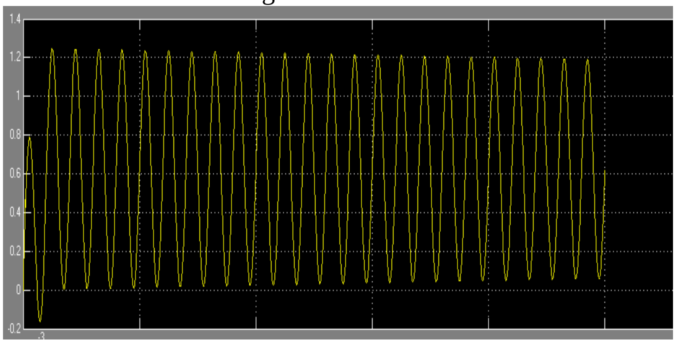


Fig. 9 Transient voltage waveform during Opening operation of CB for 10mts GIS, with variable Arc Resistance

Assuming that there is a second re-strike, another switch is connected in parallel to the circuit breaker for simulation in MATLAB 7.8. Transients are calculated by closing this switch when voltage difference across the contacts of the circuit breaker reaches maximum value. Transients calculated due to second re-strike gives the peak voltage of 1.82 p.u at arise time of 50ns as shown in Fig 10. The magnitudes and rise times of 5mts length GIS are Table II

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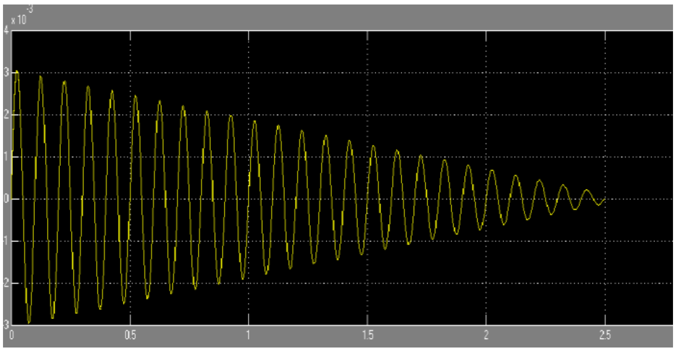

Fig. 10 transient voltage waveform during Second Re-strike for 10mts GIS, with Variable Arc Resistance

V. CONCLUSION

The variable arc resistance is calculated by Toepler's formulae. Transients are calculated due to switching operations and faults with variable Arc resistance along with load. For any length of GIS it was found that transients due to variable arc resistance give lower value of peak voltages than that obtained with fixed arc resistance. When load is connected at the open end of GIS, the peak voltages that are obtained due to faults do not follow a definite pattern

The peak magnitude of fast transient currents generated during switching event changes from one position to another in a 220kv GIS for a particular switching operation. **..** The fast transient overvoltages obtained are due to switching operations and with fixed resistance and variable arc resistance for different lengths of GIS.

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