Abstract: In our country a few Gas Insulated Substations (GIS) units have been in operation and large number of units is under various stages of installation. Although GIS have been in operation for several years, some of the problems need attention. These problems include, generation of over voltage during dis-connector operations, line to enclosure faults etc. These over voltages are caused in two ways, viz., due to switching operations of circuit breaker and line to enclosure faults. In this paper, very fast transient over voltages are generated due to switching operations have been analyzed and presented. Since the contact speed of dis-connector switches is low, re-striking occurs many times before the current interruption is completed. Each re-striking generates transient over voltage with different levels of magnitude. Since these transients have traveling wave behavior, they travel to the external systems through enclosures, bushings, cable joints etc., and cause damage to the outside equipment. They can lead to secondary breakdowns in GIS and may give rise to electromagnetic interference. Thus it is important to develop a suitable simulation models for estimation of these over voltages.

Key words: Gas Insulated Substation (GIS), Transient over voltages, switching operations, line faults and Control circuitry.

I. INTRODUCTION

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 voltages are developed. These VFTO’s are caused by switching operations and line-to-enclosure faults. When a dis-connector switch is opened on a floating section of switchgear, a trapped charge may be left on the floating section. In the opening operation of dis-connector switch, transients are produced and the magnitude of these transients and rise times depend on the circuit parameters. 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. VFT can be divided into internal and external. Internal transient create overvoltage between conductor and enclosure which can cause stress on the internal insulation of the GIS. External VFT is travelling waves and propagation outside GIS. These include transient enclosure voltage (TEV) between encapsulation and earth, transient electromagnetic fields (TEMF) radiated from enclosure which can cause stress on the secondary equipments and overvoltage on adjacent equipments. The maximum magnitude of the transient over voltage is 2.0 p.u. this value is largely dependent upon the level of trapped charge on the GIS bus bar existing at the time of the re-strike. The amplitude of trapped charge is strongly influenced by the asymmetry of the inter-contact break down voltage occurring on the fixed and mobbing contacts of the dis-connector. This paper is aimed at calculating magnitude of fast transient over voltages in GIS due to Switching Operations and Line-to-Enclosure faults by suitably modeling a typical GIS system. A comparison is made for different lengths of GIS. For better understanding of the transients, they are calculated with Fixed Arc Resistance and with Variable Arc Resistance. Attempts have been made to compare the transients with Load and without Load. Therefore in the present study, the following work has been carried out.

1. The maximum possible VFTO level for 245KV substation is estimated.
2. The effect of each component of GIS on the VFTO level is estimated separately.
3. The length of the cable termination depends on station configuration. From VFTO point of view, minimum length of the cable is estimated by considering different switching operations.
4. A model of the spark channel development is proposed for estimating the VFTO level.

II. MODELLING OF 245 KV GIS SYSTEM

A GIS system comprising of an Input Cable, Spacer, Dis-connector Switch, Bus bar of 5mts length and load has been considered for modeling into electrical network and analysis. The Fast Transient Over voltage waveform generated during Closing and Opening operation of Dis-connector Switch and Line-to-Enclosure faults has been considered for calculations. Spacers are simulated by lumped Capacitance. The Inductance of the bus duct is calculated from the diameters of Conductor and Enclosure. Capacitances are calculated on the basis of actual diameters of inner and outer cylinders of central conductor and outer enclosure. Cone Insulators used for supporting inner conductor against outer enclosure are assumed to be disk type for approximate calculation of spacer capacitance. The bus duct can be modeled as a series of Pi-network or as sequence parameters. However in this model, it is considered as distributed Pi-network. The Schematic Diagram of a Typical Gas Insulated System (GIS) is shown in below figure 1.
3 MODELLING DIAGRAM OF 245KV GIS

III. EQUIVALENT CIRCUIT FOR 245KV GIS

The bus duct is divided into three sections of length 2.5mts, 1.5mts, and 1.0mts respectively from load side. The GIS bushing is represented by a capacitance of 200pf. A Fixed Resistance of 2ohms of the spark channel is connected in series with the circuit breaker. The equivalent circuit is shown in figure 4. 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 voltages on each side will collapse initially zero and hence creating two 1.0 p.u voltage steps of opposite polarities. In this, it is assumed that re-striking is created at 1.0 p.u and -1.0 p.u respectively on either side of dis-connector Switch (DS). The transients due to different switching operations are observed.

Fig 4 Single - Phase Equivalent Circuit For 5mts Length GIS Due to Switching Operation
IV. TRANSIENTS DUE TO SWITCHING OPERATION

1 Equivalent Circuit for 5mts Length:

![Equivalent Circuit for 5mts Length](image)

Fig 13 5mts Length GIS With Variable Arc Resistance Due To Switching Operation

Fig 14 Transient Voltage Waveform during Closing Operation of CB for 5mts GIS, With Variable Arc Resistance
V. SUPPRESSION OF OVERVOLTAGES

The fast transient over voltages during switching operation and faults can cause damage to the system equipment. Hence it is advisable to suppress these over voltages for protection of equipments. One of the methods of suppressing these over voltages is by insertion of resistance during switching. Generally a Resistor of 500Ω is used for this purpose. In this analysis, a resistor of 500Ω is connected in parallel with the circuit breaker and a switch is connected in series with the resistor. The transient over voltages are suppressed only if the current during contact operation flows through the resistor. The switch connected in series with the resistor is closed at the time maximum voltage is obtained during second re-strike / pre-strike at the load end.
VI. RESULTS AND SUMMARY

By the switching operations and line-to-enclosure faults in a Gas Insulated Substation (GIS) leads to Very Fast Transient Over voltages (VFTO), these VFTO’s stress the equipments in GIS and reduces the reliability of the switchgear equipment. For knowing the maximum values of VFTO, the PSPICE software is used and a simulation is carried out by designing suitable equivalent circuits and its models are developed. The main advantage of such models is used to enable the transient analysis in GIS. 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 modeled as distributed pi-network. The transients due to switching operations and line to enclosure faults with fixed arc resistance for different lengths of GIS are found. Transients are calculated along with load and it was observed that the transients obtained in 5mts length GIS will effect the system more than that obtained in 10mts length GIS. As the distance between the fault point and load increases during fault analysis the magnitudes and rise times of the transients also increases. Transients are also calculated due to switching operations and faults with variable arc resistance for different lengths of GIS were found. It was observed that the transients due to variable arc resistance give lower value of peak voltages than that obtained in with fixed arc resistance. The transient over voltages caused by a switching operation for different lengths of GIS was suppressed by choosing appropriate value of resistance connected in series with the switch.
transients obtained during closing operation of the circuit breaker with fixed and variable arc resistance are calculated and found that the difference between peak values in both the cases is significant and that higher peaks are obtained when fixed arc resistance is used. Transients obtained during closing operation of the circuit breaker, have no significant change in magnitude of voltages.

VI. CONCLUSION

The fast transient over voltages are obtained due to switching operations and short-circuit faults are studied. The transients are calculated initially with fixed arc resistance and then variable arc resistance. The variable arc resistance is calculated by using Toepler’s formulae. Transients along with load and without load are also estimated. Transients due to trade, such as “3½ in disk drive.” Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation. Short-circuit are obtained by creating fault at different lengths of GIS from load side. At the end, these transients over voltages are reduced by connecting suitable resistor during switching operation. From the above studies the following observations are made.

1) It was observed that the transients obtained due to switching operations and faults in 5mts length GIS will affect the system more than that obtained in 10mts length GIS.

2) It was also found that during fault analysis, as the distance increases, the magnitude of transients also increases. However, when load is connected, these do not follow a definite pattern.

3) When load is connected at the open end of GIS, the peak voltages and rise times that are obtained due to short-circuit do not follow a particular pattern. This may be due to variation in damping due to combined effect of circuit and load parameters.

4) 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.

5) In case of 5mt and 10mt length GIS, the transients obtained due to short-circuit are more severe than the switching operation.

6) The transients obtained during opening operation of the circuit breaker with fixed and variable arc resistance are calculated and found that the difference between peak values in both the cases is significant and that higher peaks are obtained when fixed arc resistance is used.

REFERENCES


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