Modeling and Analysis of a 3-Phase 132kv GasInsulated Substation

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Abstract: -- This paper introduces Modeling of a 3- Phase 132kv Gas Insulated Substation. Such over voltages can cause mal functioning of protection circuits and control circuits and also initiates faults and influence on other components such as transformers. For designing a substation it is essential to know the maximum value of VFTO. Hence studies are carried out on estimation of the VFTO levels. For this purpose MATLAB 7.8 can be used. In MATLAB 7.8 simulation a suitable equivalent circuit is necessary for each component of the substation. Analysis of Very Fast Transient Overvoltage has been carried out using MATLAB7.8 for various switching conditions in a 3-phase 132kV gas insulated substation.

Keywords— **, MATLAB 7.8 software and Control circuitry,Gas Insulated Substation (GIS), Very Fast Transient overvoltages, Switching operations, 3 phase fault**

I. INTRODUCTION

Gas Insulated Substations (GIS) have found a broad range of applications in power systems over the last three decades because of their high reliability, easy maintenance, small ground space requirement etc.. In our country also, a few GIS units have been in operation and a large number of units are under various stages of installation[1].

GIS is based on the principle of operation of complete enclosure of all energized or live parts in a metallic encapsulation, which shields them from the external environment[2]. Compressed SF6 gas, which has excellent electrical insulating properties, is employed as the insulating medium between the encapsulation and the energized parts. Gas Insulated Substations have a grounded outer sheath enclosing the high voltage inner conductor unlike conventional equipment whose closest ground is the earth surface[3][4].

The Basic Insulation Level (BIL) required for a Gas Insulated Substation (GIS) is different from that of the conventional substation because of certain unique properties of the former[5]. Gas insulated bus has a surge impedance (70 Ohm) more than that of the conventional oil filled cables, but much less than that of a over head line (300 – 400 Ohms)[6].

In addition, the GIS is totally enclosed and therefore is free from any atmospheric contamination. Hence, in general the GIS permit lower BIL rating than the conventional one. A GIS requires less number of lightning arresters than a conventional one[7]. The representation of bushing is important for simulating the fast transients. Generally, the transit time through a bushing is comparable to or greater than the rise time of GIS generated transients. For this reason, bushings cannot be considered as a lumped element in estimating the VFTO level.

The generation of fast transients can be classified into two types. They are due to the following:

a) Dis-connector switch operation
b) Faults between Bus bar and Enclosure

In case of 3-phase fault, the voltage collapse at the fault location occurs in a similar way as in dis-connector gap during re-striking. By this event, step shape traveling surges are injected. For such a surge source inside GIS, two surges traveling in opposite directions are generated. However, if voltage collapse occurs at the open end of GIS, only single surge propagates on the bus[8].

During recent field tests on a 132KV substation, measurements were made of the trapped charge left when a DS was opened onto a floating section of switchgear. Numerous measurements led to the conclusion that for this switch, a potential of 0.1 – 0.2p.u is left on the floating section and that this result is consistent [9][10].

II. ESTIMATION OF 132KV GAS INSULATED SUBSTATION

During the switching operation of the circuit, the transients are developed. By the calculated values of the circuit parameters in previous chapter, the equivalent circuits are constructed by using MATLAB 7.8 software. By using the circuits the transients are calculated for different lengths of Gas insulated substation. The transients are also calculated during the faults with and without load at different distances.

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 3-phase fault in 132KvGIS . Using MATLAB of the equivalent models is developed.

A. Spacers capacitance

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.

B. Calculation of short circuit inductance &Resistance:

Assuming a short circuit fault level of 1000 MVA for 220KV system voltage, inductance and resistance are calculated as follows:

$$I_{ph} = \frac{S}{V_{ph}} \quad \text{And} \quad \%Z = \frac{X * I}{V}$$

$$\therefore \quad X = \%Z * \frac{V}{I}$$

$$\text{But} \quad X = 2 * \pi * f * L$$

$$\therefore \quad L = \frac{X}{2 * \pi * f}$$

C. Calculation of Inductance due to Load (Transformer):

For 600MVA,, 220KV transformer with 10% impedanceand 0.8 power factor the inductance is calculated as follows:

$$\sqrt{3} * V * I * \cos\phi = P$$

$$\therefore \quad I = \frac{P}{\sqrt{3} * V * \cos\phi}$$

$$\text{And} \quad \%Z = \frac{X * I}{V}$$

$$\therefore \quad X = \%Z * \frac{V}{I}$$

$$\text{But} \quad X = 2 * \pi * f * L$$

$$\therefore \quad L = \frac{X}{2 * \pi * f}$$

D. 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.

$$= 0.001 \times l \times \left[\ln\left(\frac{r1}{r3}\right) + \ln\left(\frac{r2}{r1}\right) + \ln\left(\frac{r4}{r3}\right) + 2 \times \frac{\left(\frac{r2}{r1}\right)^2}{1-\left(\frac{r2}{r1}\right)^2} \times \ln\left(\frac{r1}{r2}\right) - 1 \right]$$

Calculation of variable arc resistance:
The Variable arc resistance is calculated using the formula:

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

Where,
K_T = Toepler's constant
= 0.005 volt.sec/mt for SF6 under uniform fieldconditions
L = spark length in meters
q_0 = Initial charge or charge at the instant of breakdownT = 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 ohms. The integral in the denominator sums up the absolute value of current 'i' through the resistance R(t) over the time beginning at breakdown inception. Thus, it corresponds to the charge conducted through the spark channel up to time 't'.

Initial charge q_o is an important parameter while considering the non-uniform fields. But the field between the dis- connector contacts is almost uniform. Therefore q_o is very small.

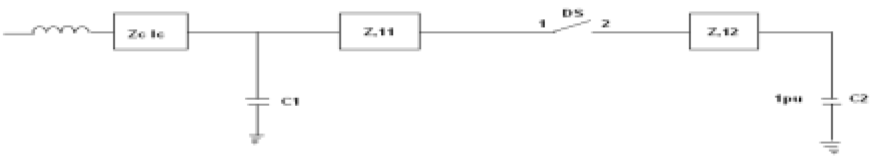

Fig 1. Equivalent circuit of GIS

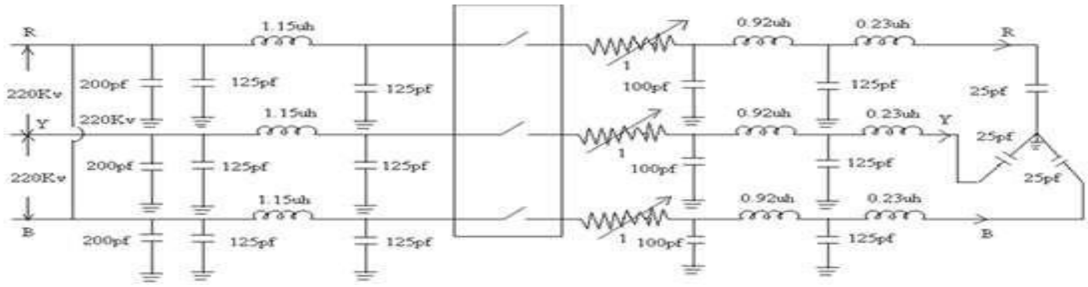

Fig. 2. Equivalent circuit for 10mtrs. Length in a 3 -phase to132kv GIS

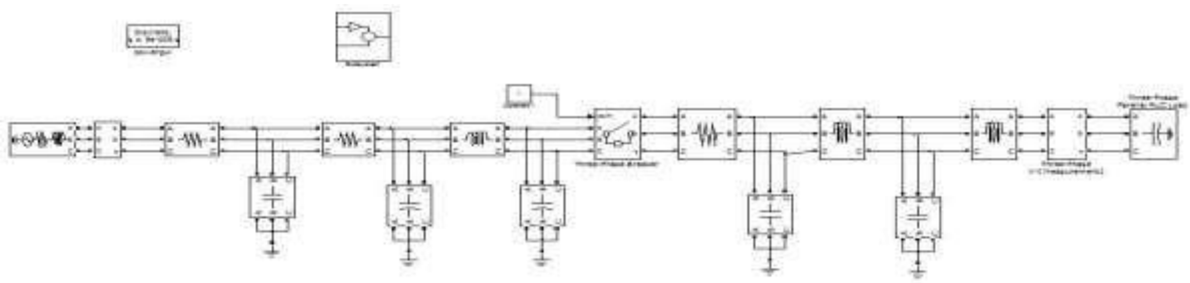

Fig. 3. MATLAB circuit for 10mtrs length in a 3-phase to 132KV GIS

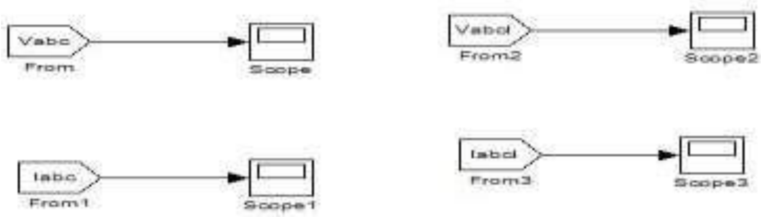

Fig. 4. Sub Circuit of 132 kV GIS

II. EQUIVALENT CIRCUIT FOR 132KV GIS SYSTEM

This circuit is divided into three sections of 1mtr, 4mtrs and 5mtrs respectively from load side and by using the circuit shown below figure 1 & 2.

The Fast transient over voltages are generated not only due to switching operations but also due to 3- phase fault in 132Kv GIS .The bus duct is dividing into three sections of length from load side.

The GIS bushing is represented by a capacitance of 200pf. The resistance of 1 ohm spark channel is connected in series with circuit breaker. MATLAB Circuit for 10 mtrs. length in a3-phase 132Kv GIS shown in the fig. 3 and Sub Circuit of 132 kV GIS fig.4.

The proposed method implemented on MATLAB 7.8. the voltage before and after circuit breaker is taken to be 1.0
p.u and -1.0pu as the most enormous condition but depending on the time of closing of circuit breaker the magnitude of the voltage on the load side changes.

For different values of voltages on the load side the magnitudes and rise time of the voltage wave are calculated keeping source side voltages as constant as 1.0p.u the values are tabulated in table I.

Similarly by changing the magnitudes of the voltage on the source side, keeping voltage on load side constant at 1.0p.u. Then the transient due to variation of voltage on source side obtained. The values are tabulated in Table II.

TABLE I

TRANSIENT DUE TO VARIATION OF VOLTAGE ON LODE SIDE

S.no	Load side Voltag e(p.u)	Magnitude of thevoltages (p.u)			Rise Time (Nano secs)		
		VR phas e	VY phas e	VB phas e	tr	ty	tb
1	-1.0	2.42	2.40	2.43	11	12	11
2	-0.9	2.34	2.33	2.34	13	14	12
3	-0.8	2.22	2.22	2.23	09	10	11
4	-0.7	2.12	2.15	2.18	11	12	11
5	-0.6	1.87	1.84	1.86	12	11	11
6	-0.5	1.84	1.82	1.82	11	10	10
7	-0.4	1.70	1.71	1.70	12	10	11
8	-0.3	1.63	1.64	1.62	10	11	10
9	-0.2	1.45	1.43	1.42	11	10	11
10	-0.1	1.39	1.40	1.39	09	10	09

TABLE II

TRANSIENTS DUE TO VARIATION OF VOLTAGE ON SOURCE SIDE

S.no	Load side Voltage (p.u)	Magnitude of the voltages (p.u)			Rise Time (Nano secs)		
		VR phase	VY phase	VB Phase	tr	ty	tb
1	1.0	2.41	2.40	2.42	10	09	10
2	0.9	2.36	2.36	2.33	11	12	11
3	0.8	2.23	2.22	2.21	12	11	12
4	0.7	2.03	2.04	2.03	11	10	11
5	0.6	2.04	2.05	2.02	13	12	13
6	0.5	1.79	1.78	1.77	12	11	11
7	0.4	1.71	1.70	1.69	11	10	12
8	0.3	1.61	1.60	1.62	12	11	11
9	0.2	1.48	1.47	1.46	10	11	10
10	0.1	1.36	1.35	1.36	09	10	11

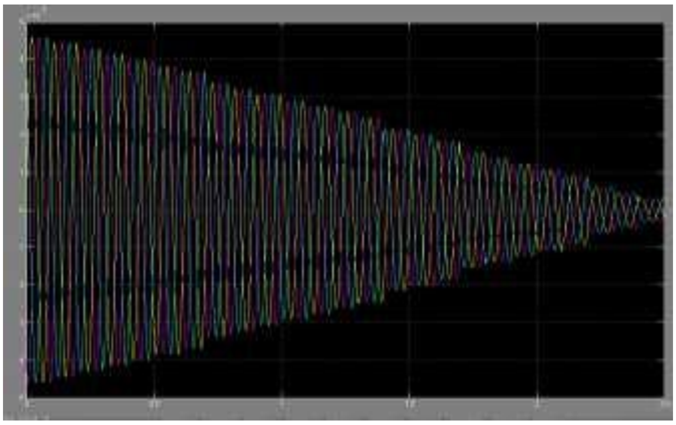

Fig. 5 Current waveform during closing operation of CB for 10mts length in a 3-phase 132kv GIS

III. RESULTS AND DISCUSSION

The various current and transient voltage at different positions in a 3-phase 132kv GIS for the first switching operation presented in results.

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 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.

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.

During closed operation, the current through the resistance of the circuit breaker is shown in fig.5 From the graph it was found the maximum current is 35A at a rise time of 14ns.The transients due to closing of the circuit breaker are calculated as shown in fig 6. From this graph, the peak voltages obtained are 2.44, 2.43 and 2.44p.u at rise times of 69, 68.69ns respectively.

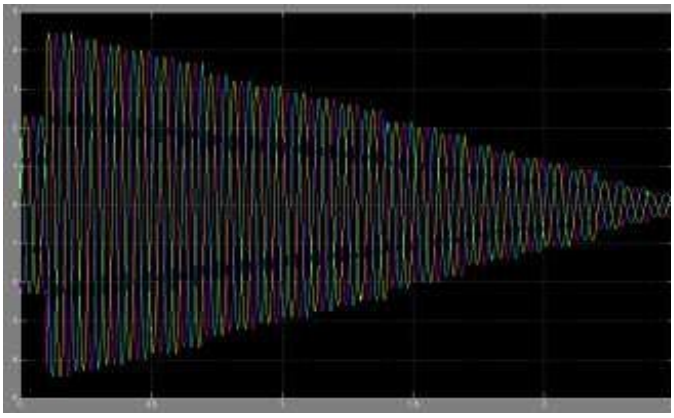

Fig 6 Transient voltage wave from during closing operationof CB for 10mts length in a 3-phase 132kv GIS

To introduce current chopping the circuit breaker is opened. The transients obtained during opening operation are shown in Fig 6.4. From the graph, the maximum voltages obtained are 1.23, 1.22 and 1.21p.u. at rise times of 61,60,and 61ns respectively. MATLAB Circuit for 10mtrs. Length in a 3- phase 220kv GIS shown in the fig 3
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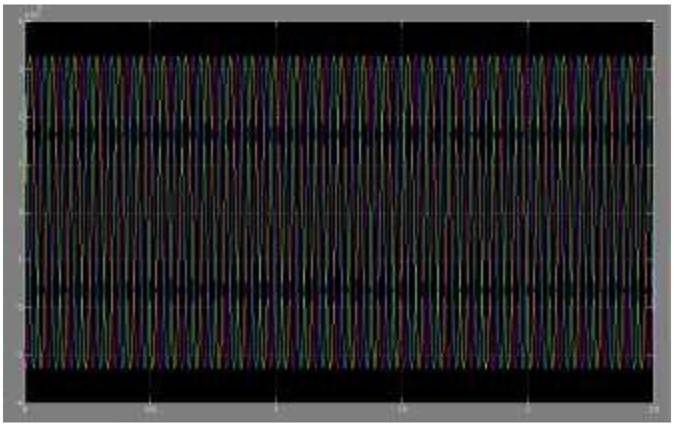

Fig. 7 Transient voltage waveform during opening operationof CB for 10mts length in a 3-phase 132kv GIS

Assuming a second re-strike occurs the transients are calculated by closing another switch at the time maximum voltage difference occurs across the circuit breaker. The transients obtained due to second re-strike are shown in Fig 8

From the graph, the maximum voltages obtained is 2.51, 2.52and 2.54 p.u at arise time of 122,121 and 123ns respectively.

The magnitudes and rise times of 10mts length GIS aretabulated in the table III.

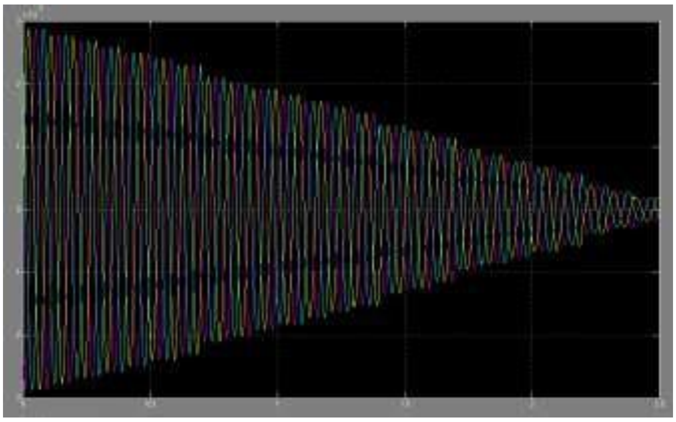

Fig.8 Transient voltage waveform during second re-strikes for 10mts length in a 3-phase 132kv GIS

TABLE III
THE ANALYSIS VALUES ARE TABULATED AS FOLLOWS:

Mode of operation	Magnitude of voltages(p.u)			Rise time (Nano sec)		
	VR phase	VY phase	VB phase	tr	ty	tb
During closing operation	2.44	2.43	2.44	69	68	69
During opening operation	1.23	1.22	1.21	61	60	61
During secondre-strike	2.51	2.52	2.54	122	121	123

III. CONCLUSION

The fast transient over voltages that are obtained due to switching operations in GIS are simulated.. It is observed that the peak magnitudes are 26% to 30% higher in case of disconnector switch closing operation. With effective design and use of the same can effectively reduce the steepness and maximum peak of VFTO generated.

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.

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