ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 1, Issue 9, November 2012

Calculation of Transient Overvoltages by using EMTP software in a 2-Phase 132KV GIS

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***Abstract*: --VFTO of a 132 kV gas insulated substation have been calculation by using EMTP 2.4 version software. This paper is focused on simulation options of the transient connection GIS-overhead line in simulation software. However, it is difficult to find a model presentation in certain software. Due to this fact, this paper shows possible ways of simulating the GIS-air connection with objects in EMTP 2.4 Software. Calculation of Transient Overvoltage has been carried out using EMTP software for various switching conditions in a 2-phase 132kV gas insulated substation.**

***Keywords*— Control circuitry, EMTP Software, Gas Insulated Substation (GIS), Transient overvoltages, Switching operations, 2-phase fault**

I. Introduction

VFT arise within a gas-insulated substation (GIS) any Time there is an instantaneous change in voltage. Most often this change occurs as the result of the opening or closing of a disconnect switch, but other events, such as the operation of a circuit breaker, the closing of a grounding switch, or the occurrence of a fault, can also cause VFT. These transients generally have a very short rise time, in the range of 4 to 100 ns, and are normally followed by oscillations having frequencies in the range of 1 to 50 MHz[1].

Their magnitude is in the range of 1.5 to 2.0 per unit of the doubleline-to-neutral voltage crest, but they can also reach values as high as 2.5 per unit. These values are generally below the BIL of the GIS and connected equipment of lower voltage classes. VFT in GIS are of greater concern at the highest voltages, for which the ratio of the BIL to the system voltage is lower[2]. Some equipment failures and arcing problems between grounded parts have occurred at system voltages above 132 kV, they have been correlated with disconnect switch and circuit breaker operation[3].

The generation and propagation of VFT from their original location throughout a GIS can produce internal and external overvoltages. The main concern are internal overvoltages between the center conductor and the enclosure. However,external VFT can be dangerous for secondary and adjacent equipment. These external transients include transient voltages between the enclosure and ground at GIS-air interfaces, voltages across insulating spacers in the vicinity of GIS current transformers, when they do not have a metallic screen on the outside surface, voltages on the secondary terminals of GIS instrument transformers, radiated electromagnetic fields (EMF) which can be dangerous to adjacent control or relay equipment[4].

VFT can also occur during switching of vacuum breakers and with certain lightning conditions. The objective of this document is to present an explanation of the VFT phenomena that can occur in GIS and provide guidelines for representing GIS components in digital simulations. Some examples with detailed input data are presented. A discussion about the accuracy of the simulations and their verification with field Measurements are also included[5].

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 disconnector 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[6].

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 [7][8].

For a range of frequencies lower than 100 MHz, a bus duct can. be represented as a lossless transmission line. The surge impedance and the travel time can be calculated from the physical dimensions of the duct. Empirical corrections are usually needed to adjust the propagation velocity.

Experimental results show that the propagation velocity in GIS ducts is close to 0.95 - 0.96% of the speed of light. The error committed by ignoring skin effect losses is usually negligible[9].

II. CALCULATION OF 3-PHASE TO 2-PHASE IN A 132KV GAS INSULATED SUBSTATION

The calculated values of the circuit parameters in previous chapter, the equivalent circuits are constructed by using EMTP 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 to 2-phase in 132Kv GIS . Using EMTP of the equivalent models is developed.

For simulating Very Fast Transient Overvoltages two concepts are important. One is the representation of the spark channel development and the other is the equivalent circuits of different GIS components under these conditions transient occur. For considering a strike across the switching contacts, voltage collapse across the disconnector during the strike and voltage drop across the disconnector after the strike occurs are important factors for estimating the VFTO levels in a GIs.

The source of these VFTO's is due to the restrikes or pre-strikes during disconnector opening or closing operations, which generate the travelling wave. Due to its construction the GIS is considered as a series of very short lengths transmission lines made up of many sections of different values of surge impedances derived from the capacitance and inductance values of each section. As a consequence there are many reflections and refractions of the travelling wave occurring at the points of discontinuity. The result is a network of high frequency overvoltages appearing within the GIS.

The Very Fast Transient Over voltages are caused by two ways, due to switching operations and line to 2-phase faults. Since the contact speed of disconnector switches is low, restriking occurs many times before the interruption is completed. Each restrike generates Very Fast Transient Over voltages with different levels of magnitude.

Isolators (also called disconnects/disconnectors) are installed in several locations in a GIS and are referred to as busbar isolators or line isolators. Two situations can be examined during switching action of an isolator.

1. Two networks are to be isolated, for example, on the right and left of the GIS; each network has its distributed inductance and capacitance. Under unfavorable conditions, there can be a phase shift between the voltage of the two networks, and a voltage of twice the system voltage can arise across the poles of the isolator (Fig. 1).

2. The second more frequent use is to connect or disconnect unloaded portions of the GIS. The second network on the right in Fig. 1, system 2, is absent and the isolator disconnects a part of GIS or overhead line from the source.

Disconnector operation typically involves slow-moving contacts that result in numerous discharges during operation. A restrike occurs every time the voltage between contacts exceeds the dielectric strength of the gaseous medium. Each restrike generates a spark, which equalizes the potential between the contacts. Following spark extinction, the source and load-side voltages again deviate and another spark occurs when the voltage across the contacts reaches new dielectric strength. Now consider the opening of disconnect with flashover.

Assume that the load side of the interrupter has trapped charge *V*1 and surge impedance *Z*1, and the source side has a trapped charge *Vs* and surge impedance *Zs*.

At the time of breakdown (sparking occurs as soon as the voltage between the source and load exceeds the dielectric strength across the contacts), the voltage on the load side goes from *V*1 to:

$$V_1 + (V_s - V_1)\frac{Z_1}{Z_1 + Z_s}$$

And the voltage on the source side goes from *Vs* to:

$$V_s - (V_s - V_1)\frac{Z_s}{Z_1 + Z_s}$$

After restrike, a high-frequency current will flow through the spark and equalize the capacitive load voltage to the source voltage. The potential difference across the contacts will fall and the spark will extinguish. A subsequent restrike occurs when the voltage between the contacts reaches the new dielectric strength level, determined by the speed of the parting of contacts and the disconnect characteristics.

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International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
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The transient magnitude of the voltage on one side of disconnect can exceed if the surge impedances differ on the two sides of the disconnector, that is, if the disconnector is near a "T" or a capacitive voltage transformer is located close to the disconnector.

In case of a line-to-ground fault, the voltage collapse at the fault location occurs in a similar way as in the disconnector gap during striking. Step-shaped travelling surges are generated and injected to GIS lines connected to the collapse location. The rise time of these surges depend on the voltage the collapse.

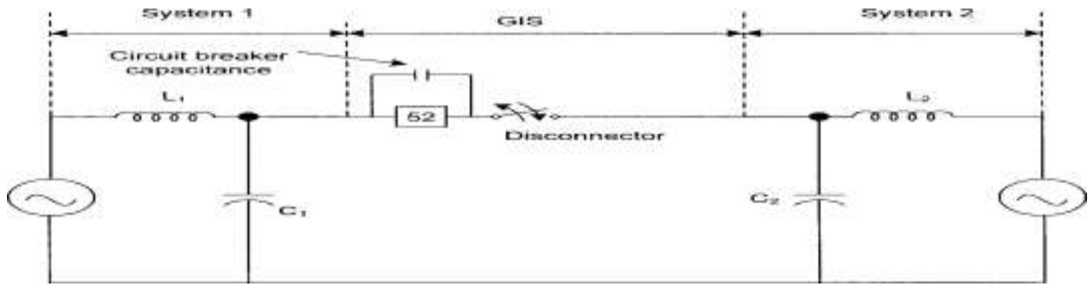

Fig 1.A disconnector in GIS, interconnecting two systems, possible switching in phase opposition

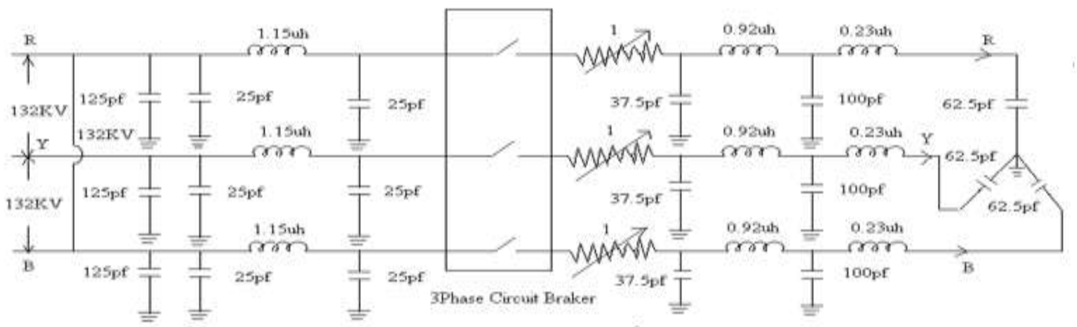

Fig. 2. Equivalent circuit for 10mtrs. Length in a 3 -phase to 2-phase of a 132kv GIS

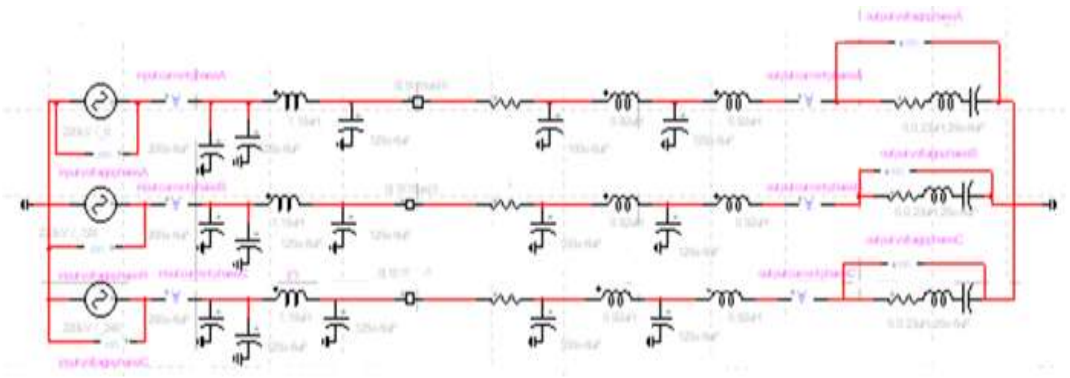

Fig. 3. EMTP circuit for 10mtrs length in a 3-phase to 2-phase of a 132KV GIS

III. EQUIVALENT CIRCUIT FOR 132KV GIS SYSTEM

This circuit is divided into three sections of 1mtrs, 4mtrs and 5mtrs respectively from load side and by the circuits shown in figure 2 & 3.are made use of. In a 3-phase circuit one phase (say phase B) has been earthed. This in effect makes the transmission line of 2-phases only. The EMTP circuit of the same will be as shown in Fig 3

The Fast transient over voltages are generated not only due to switching operations but also due to 3-phase to 2-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 125pf. The resistance of 1 ohm spark channel is connected in series with circuit breaker. EMTP Circuit for 10 mtrs. Length in a 3-phase to2-phase 132Kv GIS shown in the fig. 3.

The proposed method implemented on EMTP 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 Voltage (p.u)	Magnitude of the voltages (p.u)		Rise Time (Nano secs)	
		VR phase	VY phase	tr	ty
1	-1.0	2.44	2.43	11	12
2	-0.9	2.33	2.35	12	13
3	-0.8	2.27	2.25	12	12
4	-0.7	2.15	2.14	12	11
5	-0.6	1.86	1.85	11	12
6	-0.5	1.88	1.87	11	10
7	-0.4	1.70	1.68	12	11
8	-0.3	1.65	1.65	13	11
9	-0.2	1.47	1.45	12	13
10	-0.1	1.40	1.39	11	10

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	tr	ty
1	1.0	2.40	2.41	12	13
2	0.9	2.36	2.38	11	12
3	0.8	2.24	2.26	12	13
4	0.7	2.05	2.04	14	11
5	0.6	2.03	2.05	13	12
6	0.5	1.80	1.79	13	13
7	0.4	1.73	1.67	12	12
8	0.3	1.66	1.64	13	12
9	0.2	1.48	1.46	12	11
10	0.1	1.36	1.37	12	12

IV. RESULTS AND DISCUSSION

The various transient voltage and current at different positions in a 3 –phase to 2-phase of a 132kv GIS for the first switching operation presented in results. The inductance of the bus bar is found out from the diameters of enclosure and conductors. The bus capacitance is calculated using formula for concentric cylinders.

The maximum values of VFTO, the EMTP 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.4 & fig 5. From the graph it was found the maximum currents is 35A & 37A at a rise times of 15ns & 14ns.

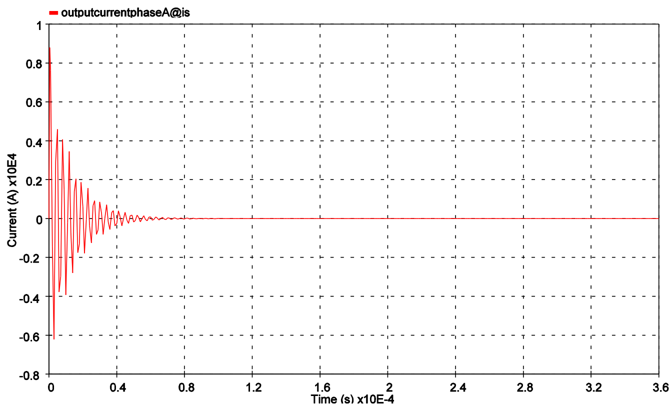

Fig. 4 Current waveform during closing operation of CB for 10mts length in a A-phase of 132kv GIS

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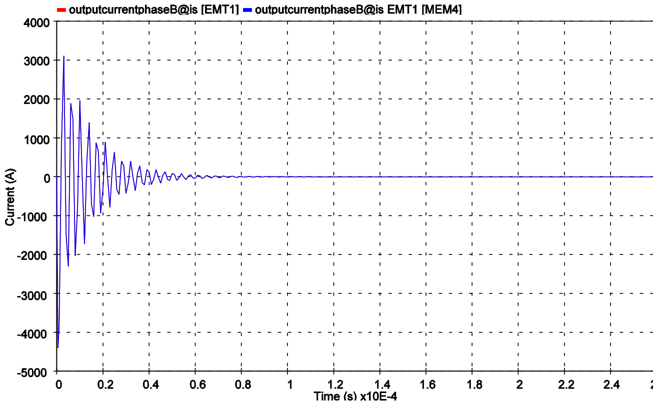

Fig. 5 Current waveform during closing operation of CB for 10mts length in a B-phase of 132kv GIS

The transients due to closing of the circuit breaker are calculated as shown in fig 6 & fig 7. From this graph, the peak voltages obtained are 2.43 and 2.44p.u at rise times of 67 and 69ns respectively. The magnitudes and rise times of 10mts length GIS are tabulated in the table III.

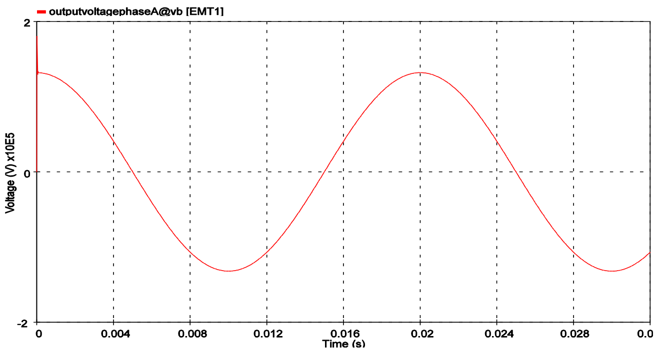

Fig 6 Transient voltage wave from during closing operation of CB for 10mts length in a A-phase of 132kv GIS

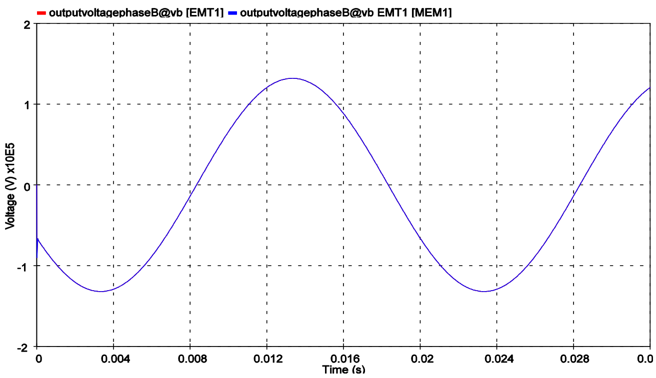

Fig 7 Transient voltage wave from during closing operation of CB for 10mts length in a B-phase of 132kv GIS

To introduce current chopping the circuit breaker is opened. The transients obtained during opening operation are shown in Fig 8. From the graph, the maximum voltages obtained are 1.22 and 1.24p.u. at rise times of 62 and 64ns respectively. The magnitudes and rise times of 10mts length GIS are tabulated in the table III. EMTP Circuit for 10mtrs. Length in a 3-phase to 2-phase 132kv GIS shown in the fig 3.

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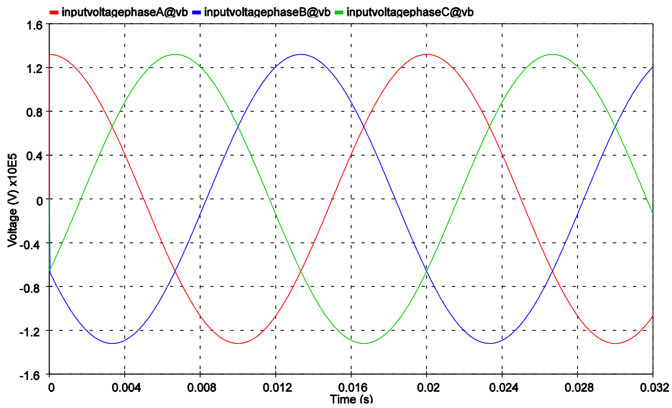

Fig. 8 Transient voltage waveform during opening operation of CB for 10mts length in a 3-phase to 2-phase(C Phase Earthed) of 132kv GIS

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 9 & fig 10. From the graph, the maximum voltages obtained is 2.53 and 2.54 p.u at arise time of 124 and 122ns respectively. The magnitudes and rise times of 10mts length GIS are tabulated in the table III.

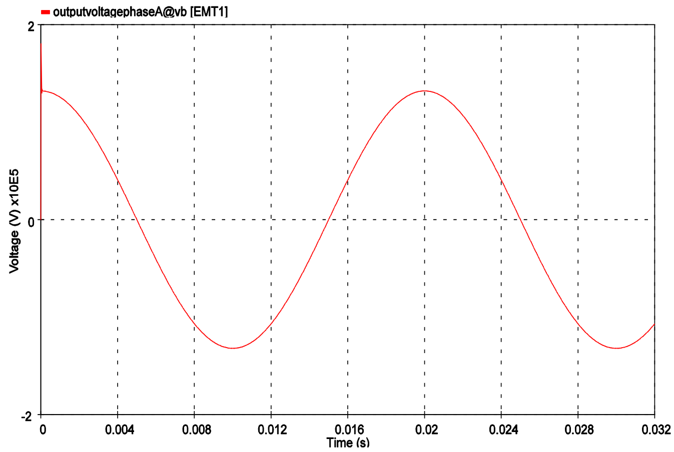

Fig.9 Transient voltage waveform during second re-strikes for 10mts length in a A-phase of 132kv GIS

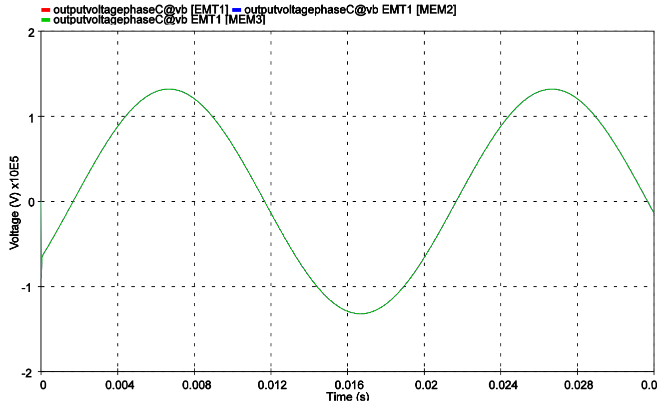

Fig.10 Transient voltage waveform during second re-strikes for 10mts length in a B-phase of 132kv GIS

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**	**tr**	**ty**
During closing operation	2.43	2.44	67	69
During opening operation	1.22	1.24	62	64
During second re-strike	2.53	2.54	124	122

V. CONCLUSION

The fast transient over voltages are obtained due to switching operation of 3-phase to 2-phase 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.

The peak magnitude of fast transient currents are generated during switching event changes from one position to another in a 3-Phaseto 2-phase from 132kv Gas insulated substations for a particular switching operation. These transients over voltages are reduced by connecting suitable resistor in an equivalent circuit during closing and opening operation.

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