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Estimation of Very Fast Transient Overvoltages by using EMTP software in a 3-Phase 400KV GIS

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***Abstract*:-- Very fast transient overvoltages (VFTOs) of the generated during switching operations in a gas-insulated substation (GIS) radiate electromagnetic transient program. This paper is focused on simulation options of the transient connection GIS-overhead line in simulation software. It is indicated that the VFTO peak-values may be restricted by increasing the length of the cable and the SF6 bus bar properly and frequency may be lowered. In addition, and the VFTO peak magnitude may be varied with the capacity of the Parallel capacitors. The very fast transient over-voltage in GIS is estimated and simulated using the EMTP software in a 3-phase 400KV Gas insulated Substation.**

***Keywords* —, 3-phase fault, EMTP Software, Gas Insulated Substation (GIS), very fast Transient overvoltages, Switching operations, Control circuitry.**

I. INTRODUCTION

The Very Fast Transient Over-voltage (VFTO) occurs when disconnector is operated in the GIS. In the system of the EHV and the UHV, the GIS equipments are more easily endangered by very fast transient over-voltage than eve, especially transformer. The model of transient circuit and parameter is vital factor for calculating the VFTO[1]. The VFTO is in line with the parameter of GIS apparatus. Hence, the magnitude and frequency of the VFTO can be influenced with the variety of the GIS apparatus parameter.

Their magnitude is in the range of 1.5 to 2.0 per unit of the 3 phase-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[2]. 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 400kV, they have been correlated with disconnect switch and circuit breaker operation [3].

The VFTO contains predominantly high frequency components range from hundreds of KHz to thousands of MHz, the transformer is regarded as lumped capacitance and lumped inductance. The SF6 bus and the cable act like transmission line with the transit time, propagation velocity and surge impedance. The values were provided by the company. Disconnector is modeled differently under open and closed conditions. When opened, it is modeled as lumped capacitances. When closed, it is replaced by the capacitance to ground. The spark is modeled as an exponentially decaying resistance in series with a small resistance. And the moving contact and fixed contact is modeled the lumped capacitance to earth [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].

Due to its high frequency nature, the VFTO imposed on the transformers connected directly to the GIS would not be distributed evenly on all transformer windings. Some windings, e.g. the first few turns connecting to the 400kV GIS, would be subject to a higher magnitude of overvoltage, Posing a potential risk of insulation breakdown of the transformers [7].

Under certain system configurations, the isolator switching operations could result in energizing or de-energizing a short section of GIS duct. Because of the relatively slow movement of the contacts of the isolator switches, pre-strikes or restrikes would occur between the contacts, creating VFTO on the GIS, and introducing a risk on the connected equipment, especially for transformer connected circuit [8]. Due to its high frequency nature, the VFTO imposed on the transformers connected directly to the

GIS would not be distributed evenly on all transformer windings. Some windings, e.g. the first few turns connecting to the 400kV GIS, would be subject to a higher magnitude of overvoltage, posing a potential risk of insulation breakdown of the transformers[9][10].

II. ESTIMATION IN A 3-PHASE 400KV GAS INSULATED SUBSTATION

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.

The transient overvoltages generated during GIS disconnector operation are a consequence of the propagation of voltage steps created by the voltage collapse across the inter-contact gap at the time of sparking. However, the resultant overvoltage shape depends on the multiple reflections and refractions of these steps at all points where they encounter impedance changes inside GIS. Both the rise time and amplitude of the initial steps as well as the configuration are instrumental in giving the transient its particular shape and peak value, as well as the configuration of GIS. In practice however, the highest frequency component that can exist and the peak transient voltage will be limited by the finite voltage collapse time, which depends on the gas pressure and is estimated to be 15ns at 0.1 MPa and reduces to 3 ns at 0.5 MPa.

Furthermore, the magnitudes of the step voltages will be fixed by the actual conditions prevailing on each side of the disconnector at the instant of flashover. This, in turn, will determine the overall peak value of the transient overvoltage. Although very steep fronted steps may be generated, the transmission line will rapidly change the wave shape such that the very high frequency content is reduced at a short distance from the disconnector switch (DS). Mechanism of switching overvoltages generation during opening of disconnector is shown in figure1.

During the operation of a disconnector switch on a capacitive load (the normal circumstances for DS operation), restrikes between contacts occur due to the relatively low speed of the moving contact. The inter-contact gap dielectric Strength does not recover fast enough compared to the transient recovery voltage V_a that appears on the contact.

V_a : Voltage across DS contacts during opening stroke
V_s : Source side voltage
V_L : Load side voltage, residual voltage
V_w : Dielectric strength across DS contacts

As the contacts bridge, the electric field between them will rise until spark over occurs. This first strike will almost inevitably occur at the peak of the power frequency voltage due to the slow operating speed of the contact. Thereafter, the current will flow through the spark and the charge on the capacitive loads gets changed to the source voltage V_s. During this period, the potential difference across the contacts falls and the spark will eventually extinguish. After this, the source side of the DS will continue to follow the power frequency and the voltage will fall from the peak value leaving the load charged. The potential difference across the DS will therefore rise again, but now with the opposite polarity and a second spark will occur when the source voltage is near zero.

The inter-contact breakdown voltage of a DS is always higher in one polarity that in the other due to the asymmetrical contact design and the first strike will take place when the moving contact has a negative polarity. Consequently, the second strike will take place for a greater potential difference than the first and will occur when the source voltage has crossed zero.

The precise number of steps and their amplitude distribution during switching will depend on the design of the disconnector switch, its operating speed and the behaviour of the GIS after each extinction of the spark. It also depends on the specific operational procedures of the GIS. In some cases, such as the opening of a circuit breaker, a floating bus bar can be charged to the maximum voltage (1 p.u). This can create severe conditions because the first spark over occurs on the peak of the power frequency source giving a charge of 2 p.u . When spark over occurs, the voltages on both the sides of the switch will collapse to zero, thus creating two 1 p.u. voltage steps (trapped change) of opposite polarity and they propagate outwards.

However, for a low speed DS, the trapped charge on the contacts when opening a pure capacitive load range from 0.1 to 0.5 p.u., with a peak value of about 0.3 p.u. This produces peak VFTO magnitudes of about 1.5 p.u. Fast operating DS, on the other hand, can leave trapped charge of 1.1 p.u. and the resulting VFTO magnitude can be as high as 2.5 p.u.. Also, on extinction of the spark between the DS contacts, the circuit on either side of the DS will oscillate at very high frequencies in the range of a few MHz's .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 a 400Kv GIS. Using EMTP of the equivalent models is developed.

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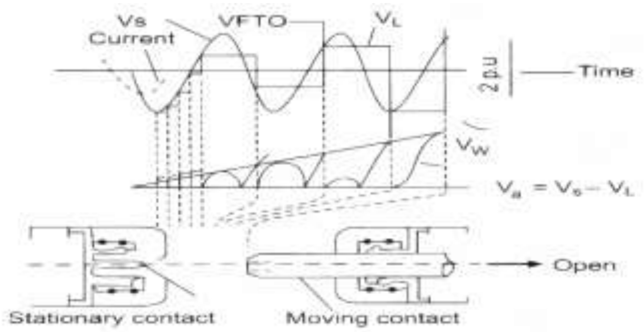

Fig 1. Mechanism of switching overvoltage generation during opening of Disconnector. The load side voltage follows the source side voltage in a Stepwise manner

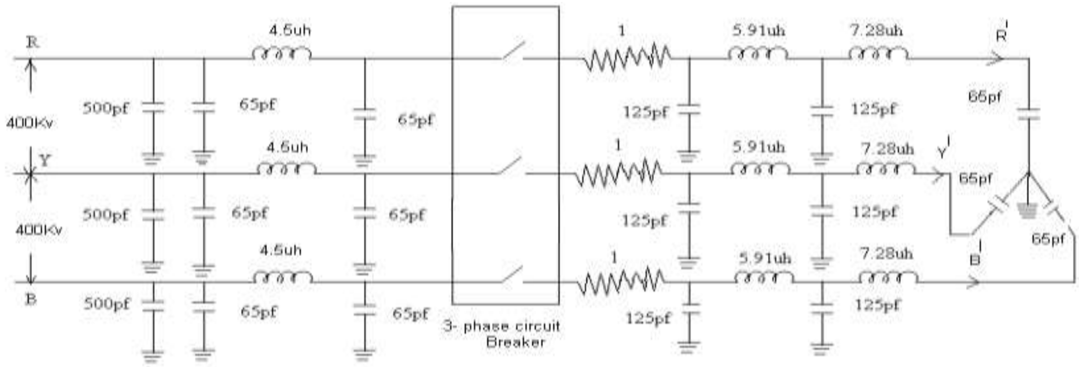

Fig. 2. Equivalent circuit for 10mtrs. Length in a 3 -phase 400kv GIS

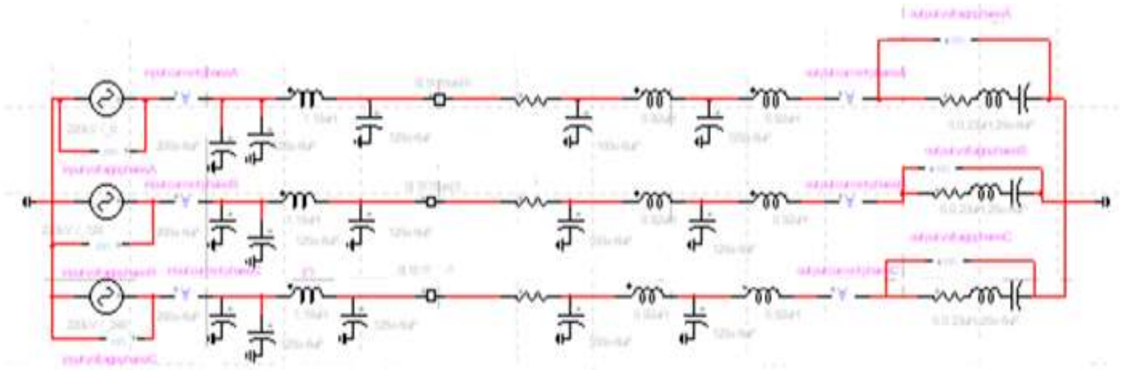

Fig. 3. EMTP circuit for 10mtrs length in a 3-phase of a 400KV GIS

III. EQUIVALENT CIRCUIT FOR 400KV 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. This in effect makes the transmission line of 3-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 fault in 400Kv GIS .The bus duct is dividing into three sections of length from load side. The GIS bushing is represented by a capacitance of 500PF. The resistance of 2.2 ohm spark channel is connected in series with circuit breaker. EMTP Circuit for 10 mtrs. Length in a 3-phase 400KV 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	VB phase	tr	ty	tb
1	-1.0	2.41	2.42	2.44	12	10	11
2	-0.9	2.33	2.34	2.35	14	13	12
3	-0.8	2.21	2.22	2.24	11	12	10
4	-0.7	2.15	2.16	2.18	10	12	13
5	-0.6	1.87	1.85	1.84	12	10	13
6	-0.5	1.83	1.85	1.84	11	12	10
7	-0.4	1.71	1.73	1.70	11	10	12
8	-0.3	1.63	1.65	1.63	12	11	11
9	-0.2	1.44	1.42	1.43	12	10	12
10	-0.1	1.38	1.40	1.37	11	10	12

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	2.42	2.40	2.41	10	11	10
2	0.9	2.36	2.36	2.33	11	12	11
3	0.8	2.23	2.23	2.21	12	11	10
4	0.7	2.06	2.04	2.04	12	10	11
5	0.6	2.06	2.05	2.05	13	11	12
6	0.5	1.79	1.76	1.78	10	12	11
7	0.4	1.70	1.70	1.68	11	10	12
8	0.3	1.61	1.63	1.64	12	12	11
9	0.2	1.48	1.46	1.45	10	10	11
10	0.1	1.37	1.36	1.36	12	10	11

IV. RESULTS AND DISCUSSION

The various transient voltage and current at different positions in a 3-phase 400KV 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 . From the graph it was found the maximum currents is 35A, 37A &36A at a rise times of 15ns, 14ns &16ns

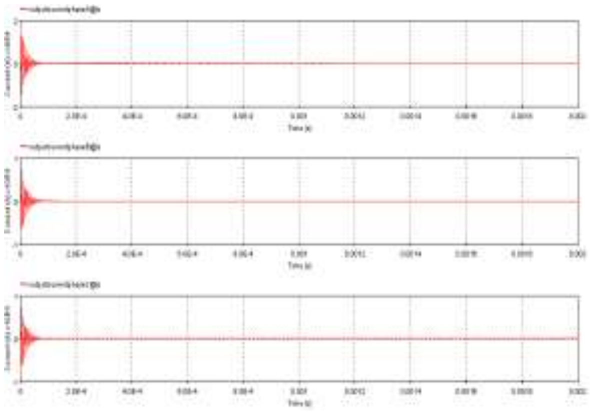

Fig. 4 Current waveform during closing operation of CB for 10mts length in a 3-phase of 400kv GIS

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The transients due to closing of the circuit breaker are calculated as shown in fig 5. From this graph, the peak voltages obtained are 2.43, 2.45 and 2.42p.u at rise times of 69, 67 and 70ns respectively. The magnitudes and rise times of 10mts length GIS are tabulated in the table III.

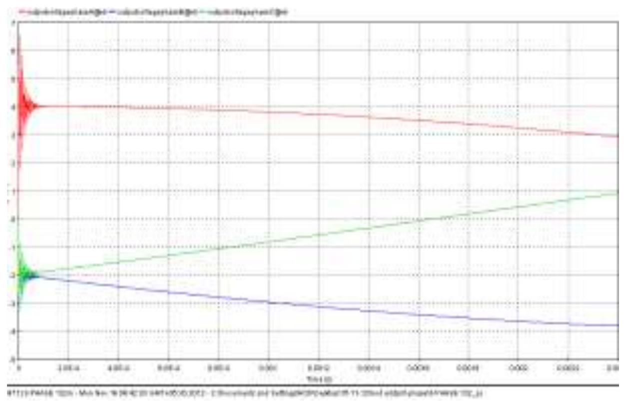

Fig 5. Transient voltage wave from during closing operation of CB for 10mts length in a 3-phase of 400kv GIS

To introduce current chopping the circuit breaker is opened. The transients obtained during opening operation are shown in Fig 6. From the graph, the maximum voltages obtained are 1.25,1.24 and 1.22p.u. at rise times of 60,62 and 62ns 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 400kv GIS shown in the fig 3.

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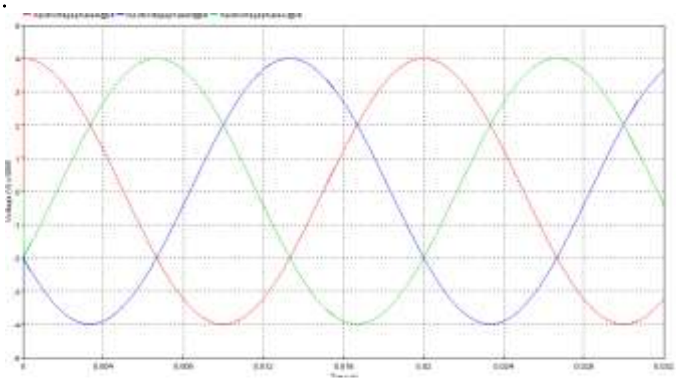

Fig. 6. Transient voltage waveform during opening operation of CB for 10mts length in a 3-phase of 400kv GIS

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 7. From the graph, the maximum voltages obtained is 2.53, 2.52 and 2.54 p.u at arise time of 124,122 and 125ns respectively. The magnitudes and rise times of 10mts length GIS are tabulated in the table III.

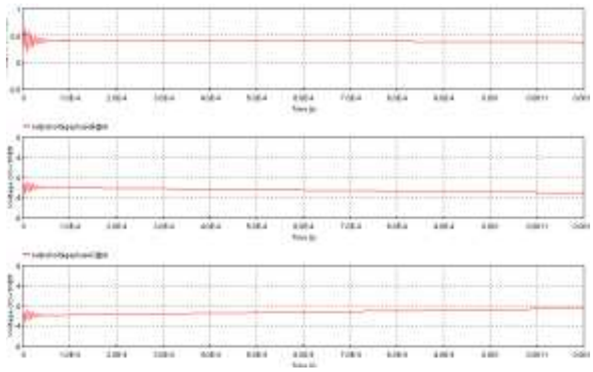

Fig.7. Transient voltage waveform during second re-strikes for 10mts length in a 3-phase of 400kv GIS

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	2.43	2.45	2.42	69	67	70
During opening operation	1.25	1.24	1.22	60	62	62
During second re-strike	2.53	2.52	2.54	124	122	125

V. CONCLUSION

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

The peak magnitudes of fast transient currents are generated during switching event changes from one position to another in a 3-Phase 400kv 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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