VFTO STUDIES DUO TO THE SWITCHING OPERATION IN GIS 132KV SUBSTATION AND EFFECTIVE FACTORS IN REDUCING THESE OVER VOLTAGES

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ABSTRACT

GIS substation due to its wide range of functions in power system due to its high reliability and easier maintenance are considered in the distribution network. For this Purpose in this paper the GIS 132KV substation model is studied[1]. In GIS 132KV with opening and closing the disconnect switch, the VFTO fast transient overvoltage with few nanoseconds forehead time is occurred[7]. This waves is released during the phase conductors and its caused tension in insulators and electrical equipment such as transformers. Transient electromagnetic field has been created, by these waves penetrates to environment by holes between GIS compartments and causes the effect on the electrical equipment and cables. These overvoltages have range about a few hundred MHz frequencies. In this substation the compartments transient voltage and its maximum amplitude at different points for different switching performance is calculated [2]. In this paper the simulations have been conducted with the EMTP software and simulation results are presented.

KEYWORDS: *GIS substation, Restrike, Switching, VFTO*

I. INTRODUCTION

The gas substations in transmission and distribution networks due to protection from pollution, high reliability, ease of development in substation, need less space have spread widely. Fast transient overvoltages that caused by switching is one of the fundamental problems that comes in this substations. Opening and closing the disconnect switch in compartment caused arc (RESTRIKE) and surge overvoltage. The following arc between the key contacts, surge voltages in conductors is published and with propagation and reflection during the conductor, it will be strengthened [3]. Due to the substantially conductive capacitive property, arc needs 2 to 4 nanoseconds. In this substation many RESTRIKES during switching operations occur. This RESTRIKE caused fast transient overvoltages that have forehead time in the range of a few nanoseconds and high oscillation frequency, that its value is less than the system BIL [1], [2]. This REATRIKE has effect on insulators and may cause FLASHOVER and thus earth error, so we need to reduce the amount of VFTO in GIS substation. Since the measuring these type of overvoltages with high frequencies is very difficult and requires the skill and accuracy as well high costs and expensive equipment, the simulation of VFTO is necessary[3]. These simulations are able to estimate the size of VFTO and its forehead time and its effect on different equipment, etc and it runs easily and correctly under actual GIS model.

II. MODELING OF EQUIPMENT

A single-line diagram of GIS substation is shown in figure 1:

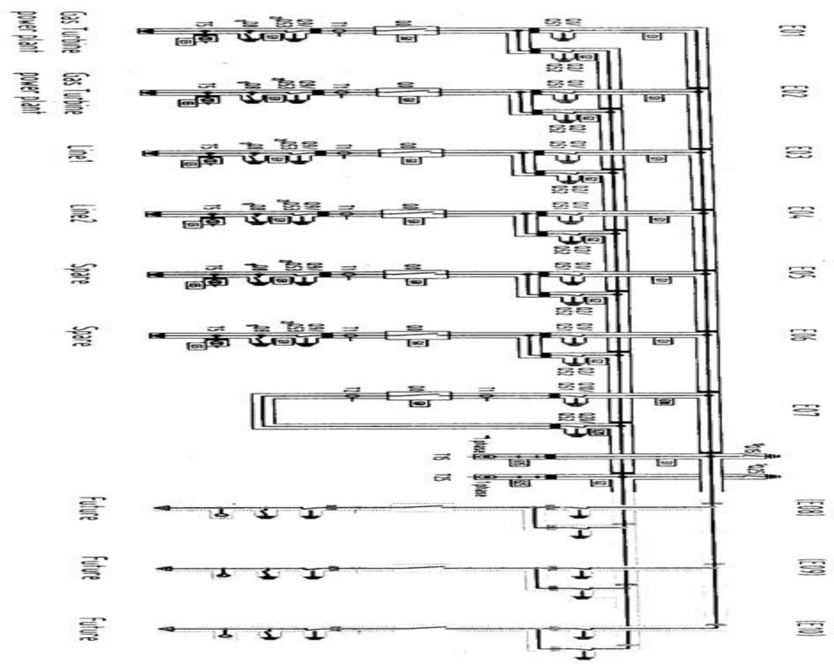

Figure 1: Single-line diagram of 132KV substation

This post includes voltage measuring transformers CVT and current measuring transformers CT, overhead transmission lines, cables, XLPE and ground keys and other equipment [4]. To calculate the transient currents, determinate the equivalent circuit of equipment and the sparks path between breaker contacts are essential. In order for modeling the equipment, integrated elements and also distributed line parameters can be used [4]. The surge impedance of the transmission line can be calculated by using the follow equation:

$$Z = 60 ln\left(\frac{b}{a}\right) \quad \Omega$$

In this equation (a) is internal diameter of high voltage bus and (b) is outer diameter of compartments as showed in figure 2:

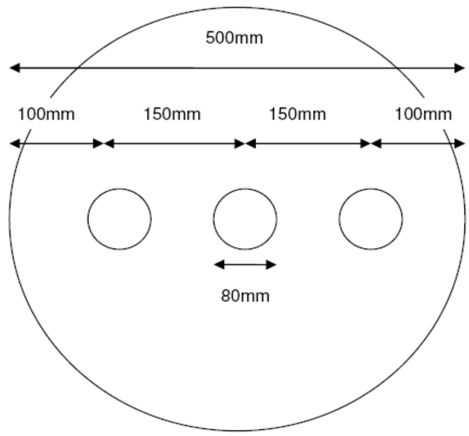

Figure 2: Internal arrangement of 132KV bus-bar

Because transient frequency is high, in the range of KHZ and MHZ, The capacitive property of in transformer is the dominant so in order to modeling them the capacitor is used. In circuit design its value is 2nf. In order to simulation, the worse case is voltage at the end of open cable. Equivalent of equipment in GIS substation are given in table 1:

Table 1: Equivalent of equipment in GIS substation

Output power lines		surge impedance=30Ω, wave propagation speed=150$\frac{m}{\mu s}$, capacitor to ground=400pf
Incoming power lines		surge impedance=30Ω, wave propagation speed=180$\frac{m}{\mu s}$
The installed transformers		capacitor to ground=2nf
Disconnect switch DS	open	surge impedance=72Ω, wave propagation speed=1.9 ns, capacity=32 pf, capacitor to ground=25pf
	close	surge impedance=72Ω, wave propagation speed=0.4 ns
Breaker CB	open	Capacitor=50 pf, surge impedance=46Ω, wave propagation speed=4.2 ns, capacitor to ground=30pf
	close	by transmission line with surge impedance=46Ω
Ground keys	CT	surge impedance=75Ω, , capacitor to ground=50pf
	PT	capacitor to ground=100pf
Arms and distances and spherical containers		equivalent to Capacitors=15 pf

The arc between contacts of disconnect switch with a 0.5Ω resistor in series has been modeled [3], [5], [6]. This resistance has a nonlinear function that shows in EMTP. It was a mathematical equation is given below:

$$R = R_0 e^{-\left(\frac{t}{T}\right)} + r$$

R_0 is 1×10^6 MΩ at the time of 1ns is placed. Figure 3 shows the above equation basis of the assumptions [6, 8, and 9].

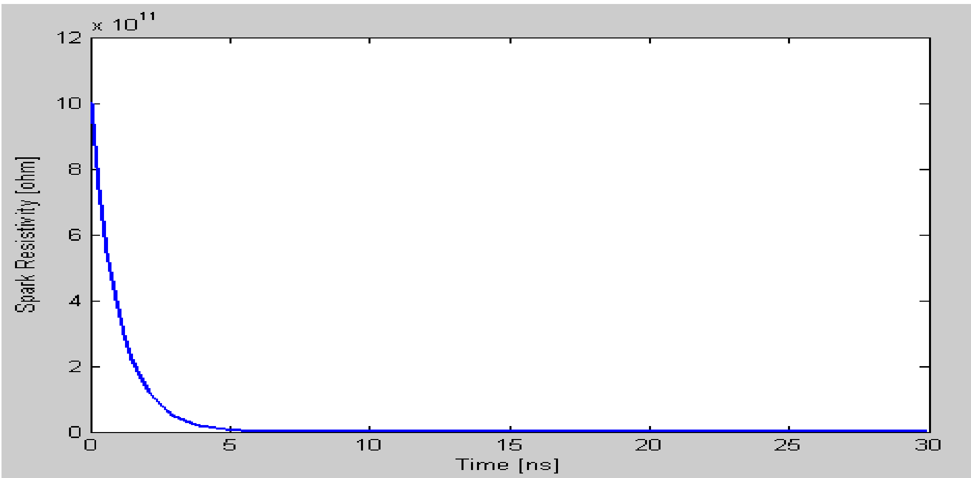

Figure 3: spark model for studies of VFTO

In figure 4 a part of model is showed in EMTP software:

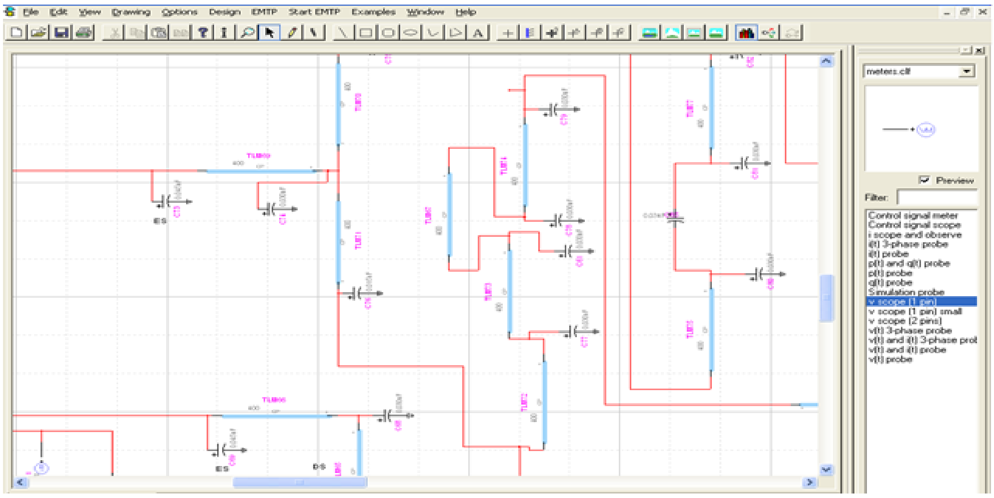

Figure 4: a part of model in EMTP software

III. SIMULATION RESULTS

Order to evaluate fast transient overvoltages caused by switching in GIS132KV substation the 6 below case is considered:

1) By assuming connector generator G1, disconnect switch and circuit breaker is closed, and the Q59 disconnect switch key operated by the same time of breaker performance.
2) Following the first case, after closing circuit disconnect switch key, assuming the closing of an additional bass, CB is acted.
3) With respect to the 1 and 2 after closing the GT1, second generator can be connected to the middle of GIS 132KV, now the condition of 1 can be considered for second generator.
4) With respect to connecting mode of GT2, the second case condition can be considered for that.
5) After the connecting of generators, one of the outputs feeder lines can be connected, this work is done in two steps. CB line through a disconnect switch can be energizing while supply line CB is open.
6) To mode 5, by assuming all of disconnect switch is operated; circuit breaker or the same supply line CB is acted.

According to the cases is achieved, to have better comparison of the results, peaks of transient voltage amplitude in switching modes in the different equipment substation is presented in Table 2.

1) VFTO near generator of performance of disconnect switch
2) VFTO near CB of performance of circuit disconnect switch
3) VFTO on both sides of the open breaker
4) VFTO in converter increases

For top switching cases, some of equipment has been studied. In order to see the results of cases, the following table was drawn. It showed the maximum amplitude of VFTO:

Table 2: maximum amplitude of VFTO

cases	switching mode 1 [V]	switching mode 2 [V]	switching mode 3 [V]	switching mode 4 [V]	switching mode 5 [V]	switching mode 6 [V]
1	1.85	-	-	-	-	-
2	1.85	-	-	-	-	-
3	1.85	1.84	1.7	1.83	1.2	1.85
4	1.5	1.5	-	-	-	-

To check these results, the waveforms in the different states can be investigated. For example to comparison the amplitude of VFTO on the sides of CB for switching modes, 5 to 8 waveforms are plotted. According to the figure it can be observed the amplitude of VFTO is dropped in figure 9.

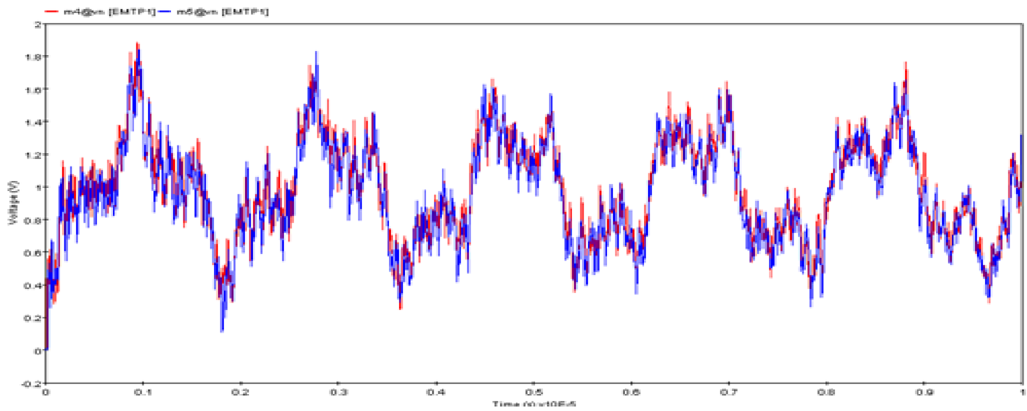

Figure 5: VFTO on the sides of CB for switching mode 1

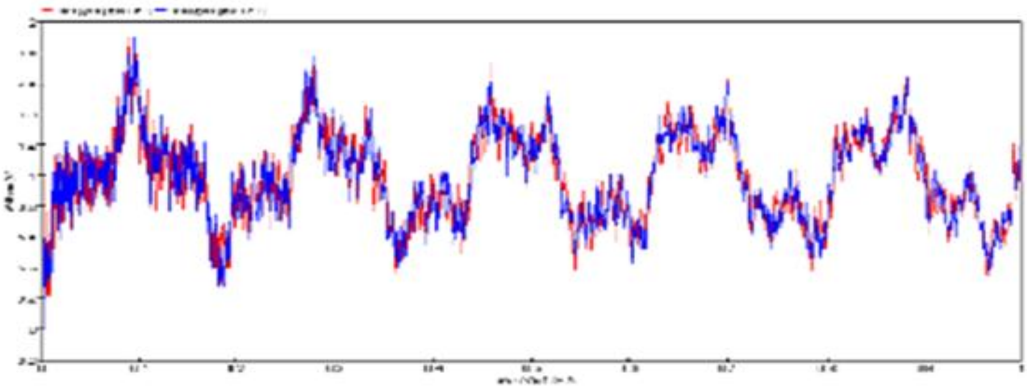

Figure 6: VFTO on the sides of CB for switching mode 2

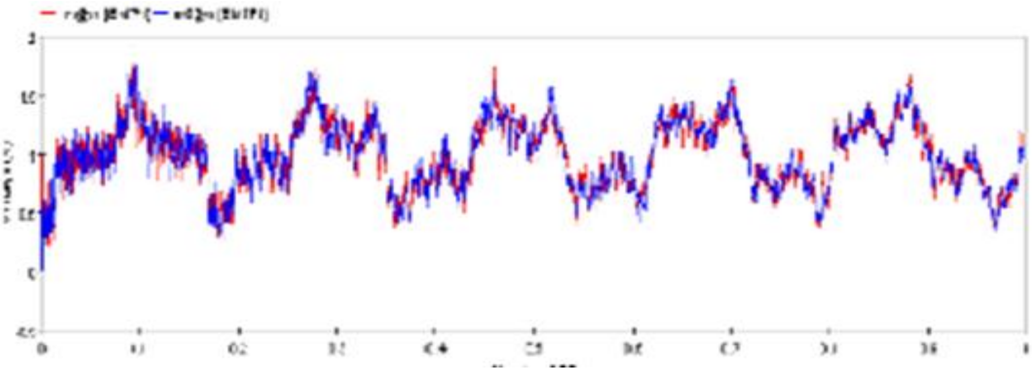

Figure 7: VFTO on the sides of CB for switching mode 3

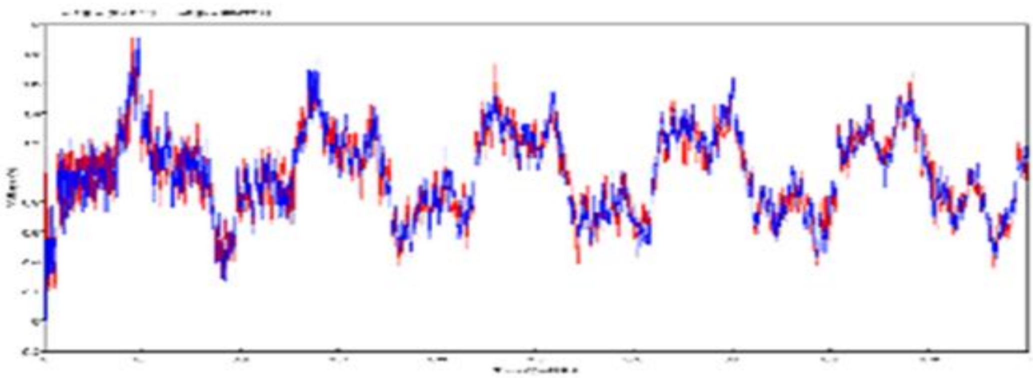

Figure 8: VFTO on the sides of CB for switching mode 4

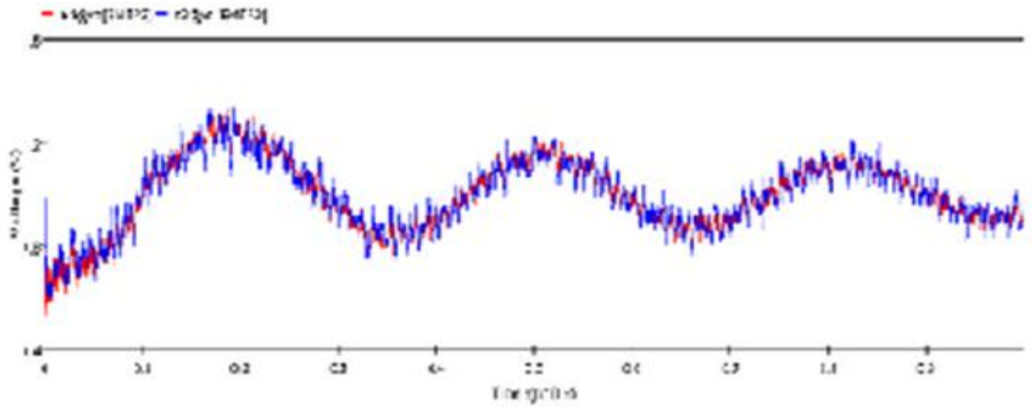

Figure 9: VFTO on the sides of CB for switching mode 5

To compare simulation results at position 6 between the cable terminals and the sides of CB the figure 10 can be considered. It is observed from that voltage at the end of cable is reduced in comparison with sides of CB.

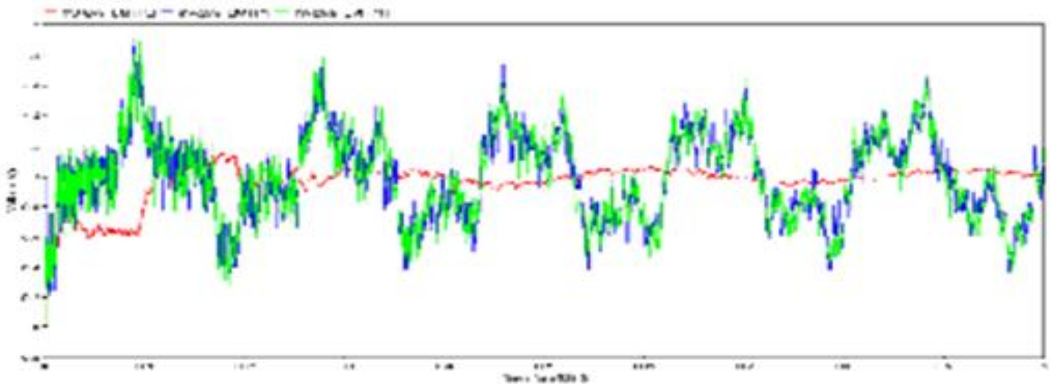

Figure 10: VFTO on the sides of CB and end of cable at position 6

With performance of all disconnect switch if CB is open from output supply line and its affiliates DS is also open, and then it can be seen that the amount VFTO in increasing converter drastically reduced. By comparison its waveforms with step 2, the decrease of that is observed:

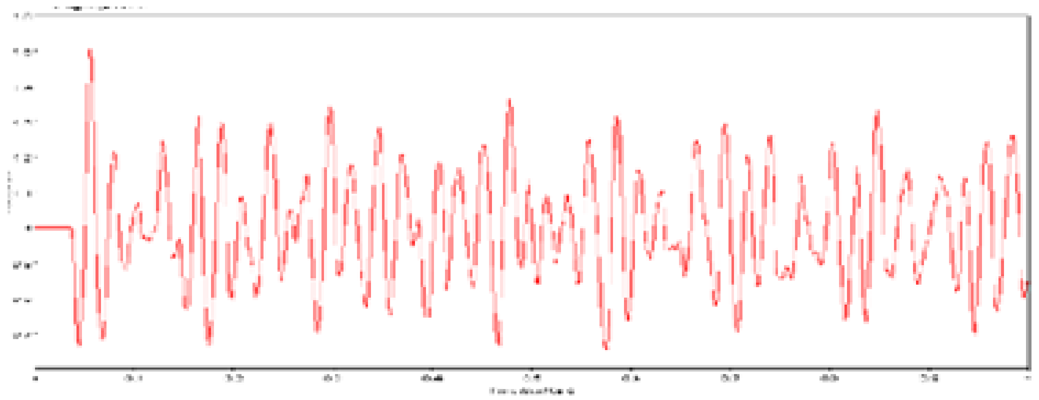

Figure 11: VFTO in increasing converter step 2

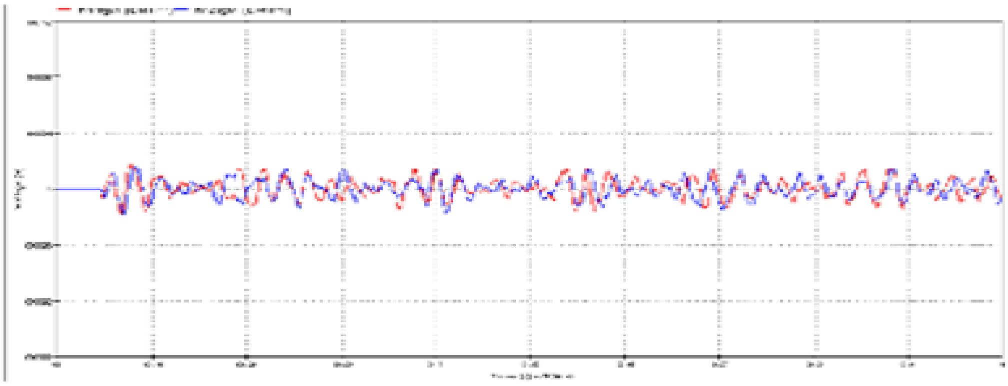

Figure 12: VFTO in Transformer

Duo to calculate the overvoltages on the sides of CB, when CB and DS are open, it can showed in figure 13:

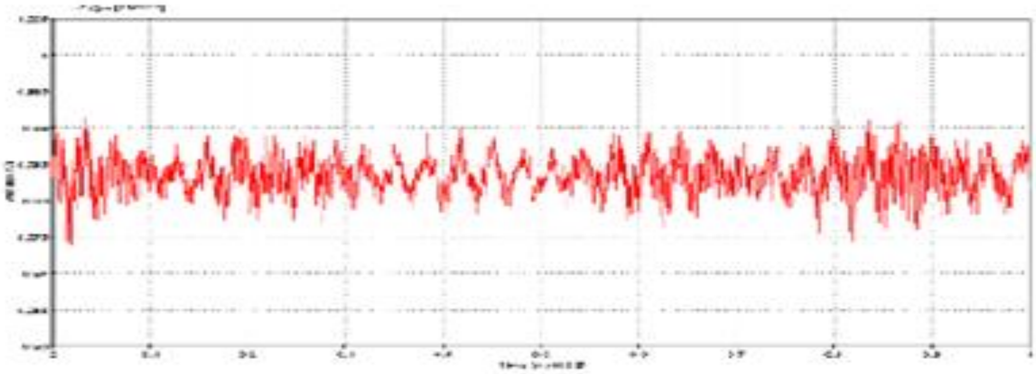

Figure 13: VFTO on the sides of CB due to openness disconnect switch

According to the results it can be seen the amount of overvoltages VFTO due to openness disconnect switch and CB has fallen sharply.

Stored charge effects at levels VFTO

Stored charge in the unit before switching positions is dependent the design of disconnecting switch and it is usually less than 0.3PU. In order to consider the effect of stored charge levels of switching, this effect can be observed for different loads and achieve waveforms for each load and in this situation evaluate the effect of switching to reduce VFTO for different load. For this purpose by drawing the table 3 the peak of VFTO amplitude on the each part of GIS substation according to the stored charge can be observed and compared the range of its variation with different loads. Results of simulation are given in table 3:

Table 3: simulation results of changing the load at high voltage bus

Stored charge In high voltage bus	0 PU	-1.2 PU	1.2 PU	1 PU	0.3 PU
VFTO in input Cable is out	0.45 (V)	-1.4 (V)	1.36 (V)	1.8 (V)	0.6 (V)
VFTO on the sides of CB	1.55 (V)	2 (V)	1.7 (V)	1.41 (V)	1.41 (V)
VFTO on the sides of closed DS	1.3 (V)	1.57 (V)	1.24 (V)	1.25 (V)	1.25 (V)
VFTO on the sides of open DS	1.3 (V)	1.6 (V)	1.26 (V)	1.25 (V)	1.25 (V)

VFTO on bus-bar	1.3 (V)	1.57 (V)	1.17 (V)	1.2 (V)	1.3 (V)
VFTO on input of transformer	1.1 (V)	1.16 (V)	1.04 (V)	1.05 (V)	1.08 (V)

It is clear by increasing load from 0.3 to 1.2, maximum amplitude of VFTO on the transformer input is decreased from 1.08 to 1.04, but at the -1.2 PU it observed the value is increased to 1.16. So it is possible by reducing the value of stored charge in to the larger load with positive sign, the amplitude of VFTO on the transformer input be reduce. We can have results for other modes of different substation equipment. As other example the comparison of waveforms for 1.2 PU and 1 PU showed in figure 14 and 15:

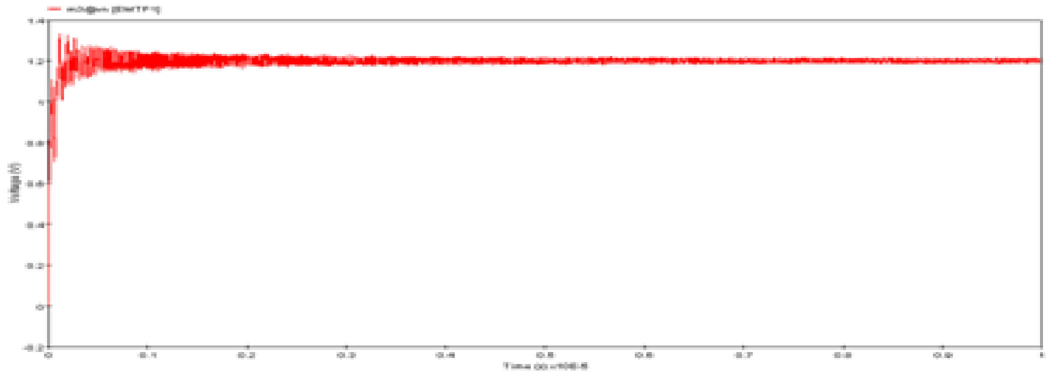

Figure 14: VFTO on the input of output cable with stored charge (1.2PU)

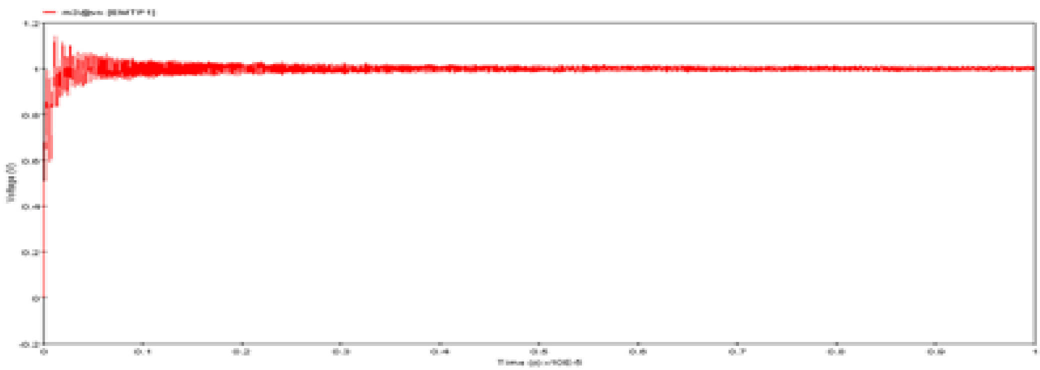

Figure 15: VFTO on the output cable with stored charge (1 PU)

According to figures 16 and 17, amplitude of VFTO on the sides of CB at 1.2 PU in high voltage bus has range about 1 PU. This range of variation at 1 PU is reduced to 0.8. It can be seen by reducing the stored charge this range of variation is reduced.

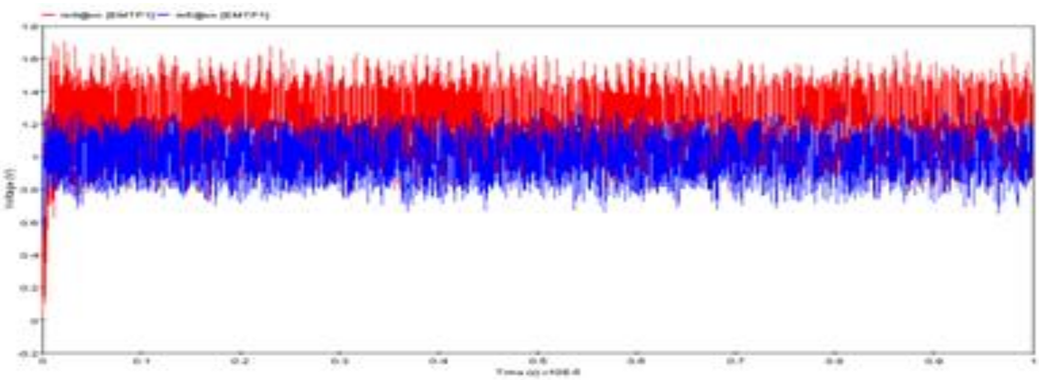

Figure 16: VFTO on the sides of CB with stored charge (1.2PU)

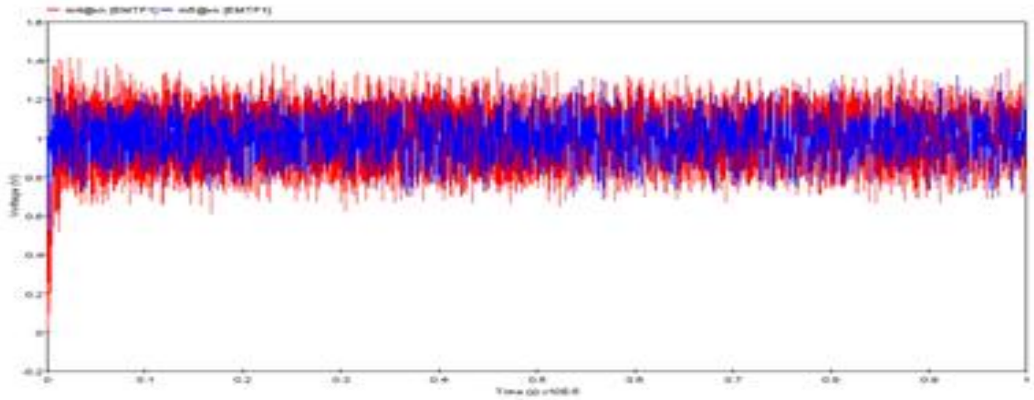

Figure 17: VFTO on the sides of CB with stored charge (1PU)

To comparison simulation results with stored charge on the sides of closed DS, figures 18 and 19 are presented:

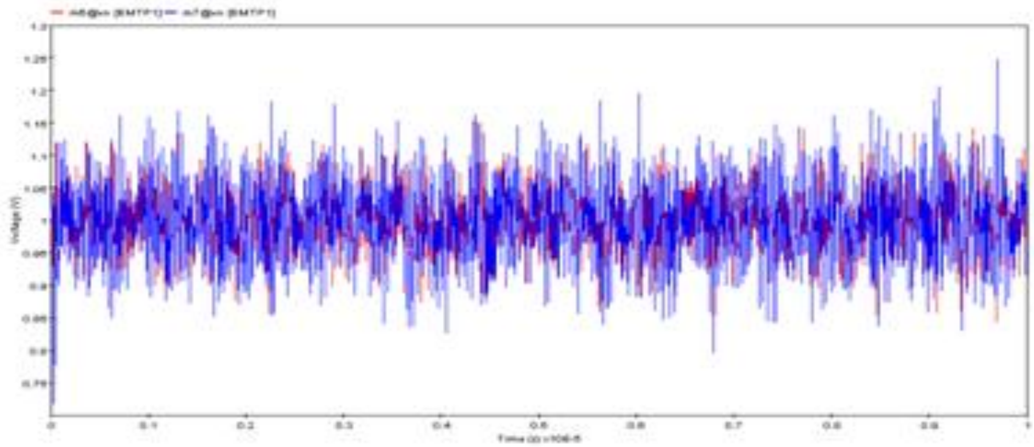

Figure 18: VFTO on the sides of closed DS with stored charge (1.2PU)

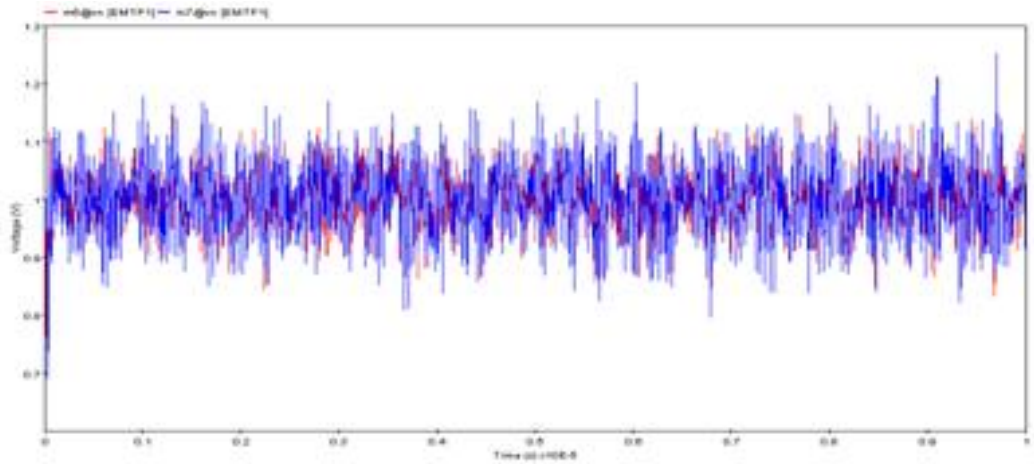

Figure 19: VFTO on the sides of closed DS with stored charge (1PU)

It is clear from these figures the range of variation at 1.2 PU is more than 1 PU. Other result is shown in figure from 20 to 23.

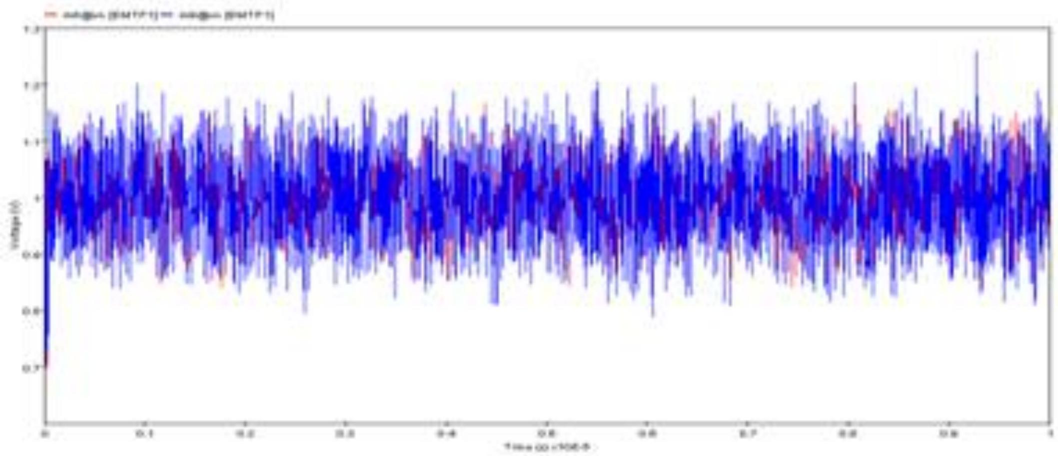

Figure 20: VFTO on the sides of open DS with stored charge (1.2PU)

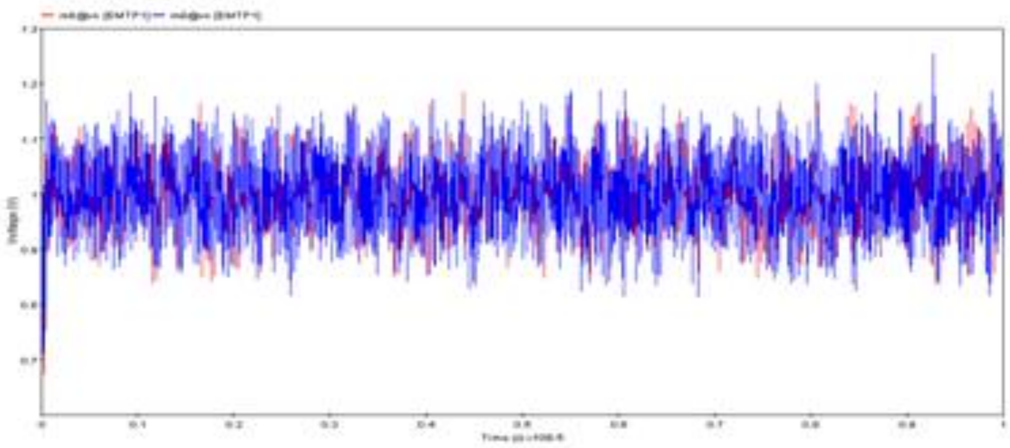

Figure 21: VFTO on the sides of open DS with stored charge (1PU)

Results at input of increasing converter are showed at follow figure:

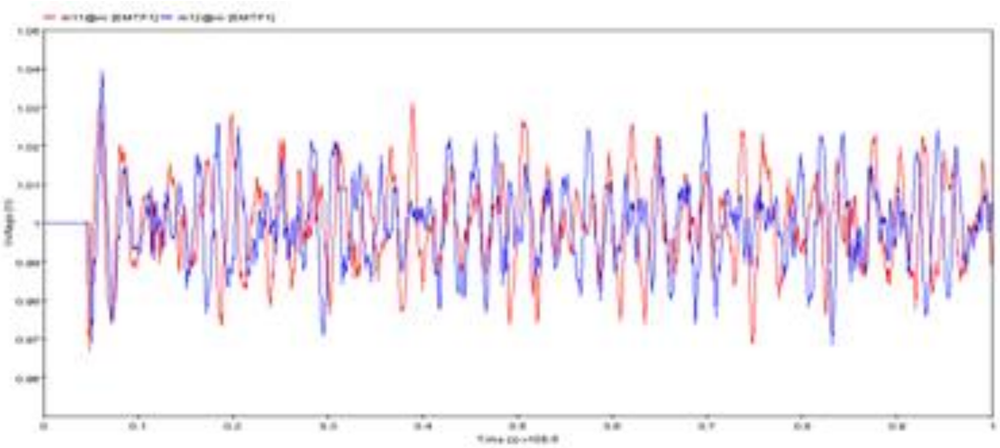

Figure 22: VFTO at input of increasing converter with stored charge (1.2PU)

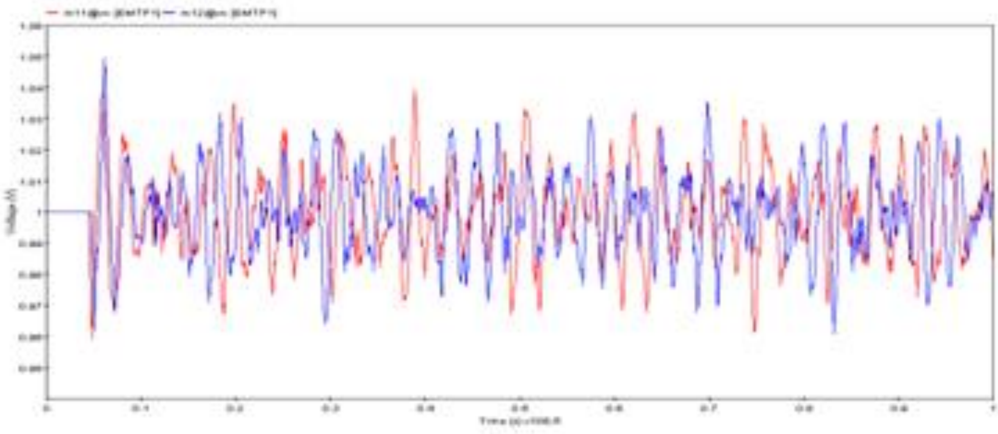

Figure 23: VFTO at input of increasing converter with stored charge (1PU)

In figures 24 and 24 the magnitude of VFTO with stored charge is presented:

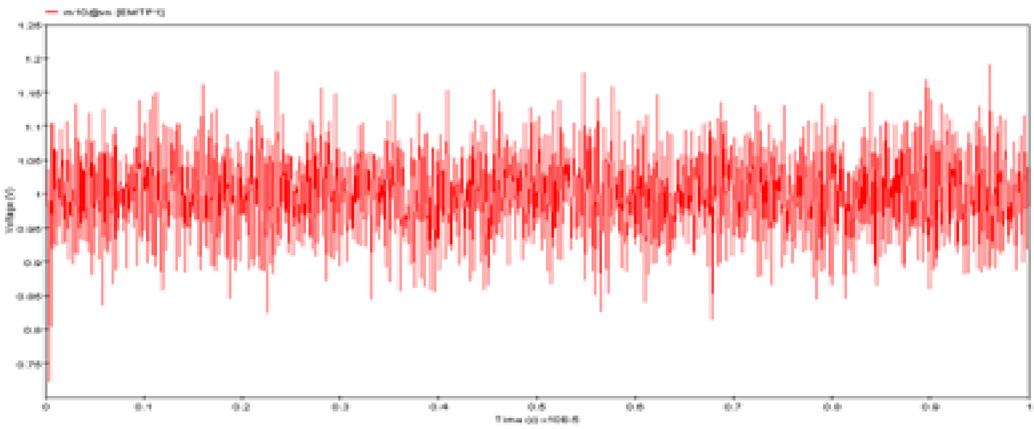

Figure 24: VFTO at bus-bar when the stored charge is 1.2 PU

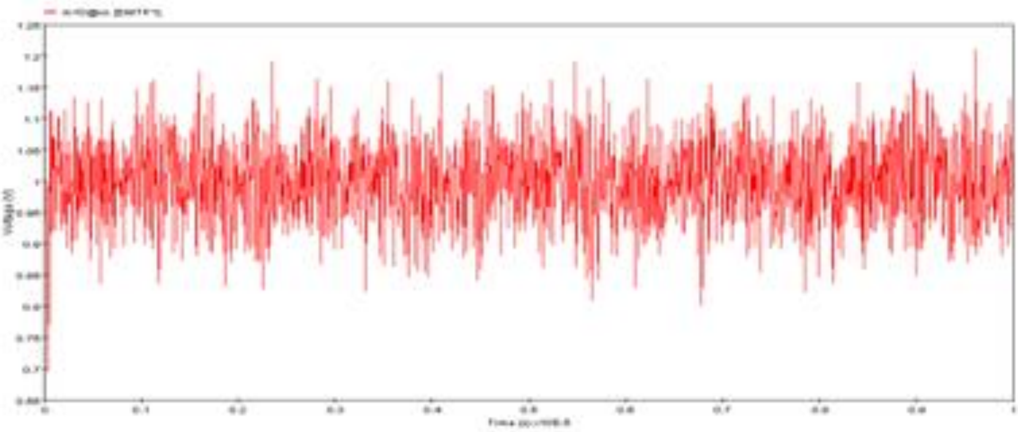

Figure 25: VFTO at bus-bar when the stored charge is 1 PU

It is clear from the results; VFTO in substation equipment is reduced specially with stored charge.

IV. CONCLUSIONS

In this paper we model different parts of GIS 132KV substation by using EMTP-RV software to study fast transient overvoltage VFTO during switching operations. These waves have very low rise time and very high amplitude near 5 PU and that isn't controllable by lightning arrester. In GIS substation, at time of switching with increasing distance from place of switching, the amplitude and frequency is reduced and by increasing speed and switching performance, Number of arc is reduced[8,2]. In this substation model is designed and parameters are chosen. High transient voltage VFTO during different switching operations has been studied. In this simulation VFTO amplitude is less than 2PU so one of the ways to reduce overvoltages VFTO, addition to using a resistor in parallel with switch is using the stored charge [2]. This means that there is no threat due to VFTO and its amplitude is reduced and there is no need to apply any kind of lightning arrester to reducing these overvoltages [5].

As future work to reduce the fast transient overvoltage VFTO, we can use RC filter in circuit and by using resistor in circuit not only will reduce this overvoltages but also its gradient is reduced.

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