Analysis of Very Fast Transient over Voltages of Transformer in Gas Insulated Substation (GIS) using Wavelet Technique

K. Prakasam, Member IAENG, M.Surya Kalavathi, Member IAENG, D.Prabhavathi

Abstract— **switching operations generates very fast transient over voltages (Very fast transient over voltages (VFTOs)) in gas insulated substations (GIS) and it is very dangerous to transformers as it causes the damage to insulation because of its short rise time. Mitigation and analysis of very fast transient over voltages (Very fast transient over voltages (VFTOs)) of power transformer is very important in gas insulated substations (GIS) as very fast transient over voltages causes' damage to the insulation of the power devices like transformer. In this research work power transformer is considered as it plays major role in the electrical substation (GIS). Initially the power transformer rating of 500MVA in 765kV/400kV gas insulated substation has been considered and the simulation model is developed using Mat Lab platform on the basis of very fast transient (VFT).Mitigation methods like shunt resistor and metal oxide surge arrester (MOA) have been employed individually and then the effect of the proposed damping methods on peak magnitude of very fast transient over voltages (Very fast transient over voltages (VFTOs)) has been evaluated. In the further stage, the effect of terminal components on peak of Very fast transient over voltages (VFTOs) has been estimated 1ns. The outcome of the proposed technique again is explored to wavelet transform (WT) (Db4) for extraction of high frequency signals. As wavelet transform (WT) is a powerful tool for analysis very fast transient signals. The results shows that peak value of Very fast transient over voltages (VFTOs) can be reduced to considerable level by employing the proposed damping methods and the terminal components of gas Insulated substation (GIS) also influences the peak magnitudes of Very fast transient over voltages (VFTOs).**

Index Terms- Keyword—analysis, damping, mitigation, surge, transients, wavelet

I.INTRODUCTION

The power framework is vast and interconnected one in which the transformer assumes a vital part and subsequently it is extremely crucial to ensure it against the inside and outer shortcomings and also from the over voltages because of any reason especially when it is utilized as a part of gas protected substation since there is dependably probability persistently the probability of explanation behind very fast transient over voltages.

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In India moreover, a couple of GIS units are under various periods of foundation. The basic insurance level (BIL) required for a gas secured substation (GIS) is not the same as that of the conventional substation by virtue of certain extraordinary properties of the past. Gas ensured substation has surge impedance (70 Ω) more than that of the customary oil filled connections, however an extraordinary arrangement not as much as that of an over head line (300 Ω - 400Ω). The essential protection level (BIL) [7] required for a gas protected substation (GIS) is not the same as that of the ordinary substation in view of certain exceptional properties of the previous. Exchanging operations create very fast transient over voltages (VFTOs) [1, 2, 7, 9] might bring about secondary breakdowns inside a GIS and transient Enclosure Voltages (TEV) outside the GIS.

II. METHOD OF EVALUATION OF VERY FAST TRANSIENT OVER VOLTAGES (VFTOs)

Numerous writers have examined about era, calculation, alleviation concealment [2, 12], estimation and investigation of very fast transient over voltages in various ways and a number of the scientists introduced their articles about relief and examination of very fast transient over voltages (Very fast transient over voltages (VFTOs) [5] in gas Insulated substations (GIS) however the greater part of them considered low voltage low appraising transformer and correlation given between the current and their proposed damping techniques. The wavelet transform (WT) gives the exact estimation [6] since the out happens to wavelet transform (WT) depends on the time and recurrence investigation, not at all like individual time area and recurrence space. The proposed 765kV/400kV, 500MVA GIS framework has been outlined on the premise of very fast transient (VFT) as very fast homeless people are voyaging wave nature. The parts of the proposed framework are planned considering surge impedance, spread speed, developmental time length and.

A. Power Transformer

The windings of transformer at high frequencies acts like capacitive system [8, 10] there by it ought to be dealt with as coactive nature, the arrangement capacitance and shunt capacitance ought to be considered to assess a definite estimation of Very fast transient over voltages (VFTOs). Since the transformer curl at high frequencies acts as capacitive system the demonstrating of transformer has been composed taking into account very fast transients (VFT)[7, 8, 9] i.e. The parameters of transformer are evaluated for exact reproduction comes about and are given by R1 = 22.8 Ω , R2=22.8 Ω,R3=300 Ω and inductance of the loops L1= 5.µH, L2 = 47.5 µH , L3 = 9.42 µH and the capacitance C1 = 0.84pF, C2 = 1.74pF, C3 = 35.4pF, C4 = 120pF the surge impedance, speed of wave, formative time and length are considered and additionally the arrangement of capacitance between the turn and curl and the shunt capacitance between the turn[6], loop and grounded center and transformer tank are considered for precise consequences of the top extent of very fast transient over voltages (Very fast transient over voltages (VFTOs).The surge impedance, propagation velocity and formative time can be evaluated from the equations (1), (2) and (3).

$$Z = \sqrt{\frac{L}{C}} ------------------ (1)$$

$$\upsilon = \frac{1}{\sqrt{LC}} ------------------ (2)$$

$$\tau = \frac{l}{\sqrt{LC}} ------------------ (3)$$

B. Disconnecting switch (DS)

In the proposed work disconnecting switch (DS) [4, 11] has been employed for switching transients and it can be designed as per open and closed conditions. During the closing operation of disconnecting switch (DS) the electric field increases still sparking occurs and the sparking occurs at power frequency first. The sparking charge depends on upon the speed of the disconnector switch (DS).The disconnector switch (DS) [4, 11] is represented by a PI section contains two travelling wave models [7], two capacitors to ground and a capacitor over the contacts as shown up fig.2 with the parameters as Z_1=34 Ω, L_1= 520mH, L_2=390mH, C_1=30pFand C_2=30pF. The radiance used as a piece of detaching switch(DS) re-strike cases is shown as an exponentially spoiling resistance Ro e(- t/τ) in course of action with a small resistance, r of 0.5 Ω to manage the waiting blaze resistance. Estimation of settled resistance r_s has been chosen on the premise of the viable thought as examined

$$L = \left(\frac{1}{1000}\right) l [\ln\frac{R1}{R3} + \ln C + \ln\left(\frac{R4}{R3}\right) + \frac{2X\left(\frac{R2}{R1}\right)^2}{1-\left(\left(\frac{R2}{R1}\right)^2\right.} X \ln\left(\frac{R1}{R2} - 1\right) \quad - (4)$$

$$C = \left(\frac{2\pi\varepsilon_0\varepsilon_r * l}{2.3 * \ln\left(\frac{b}{a}\right)}\right) --------------- (5)$$

$$R_s = R_0 * e^{-t/\tau} + R_f ------------- (6)$$

Where, R0 = 10^{12} Ω, Fixed Resistance =0.5Ω. T (spark time constant) = 1 ns, Open end section of GIS - The open ended section of GIS has been presented in the following figure where a lumped shunt capacitance has been considered. Assuming the same as a coaxial hemisphere, its capacitance has been estimated using following equation.

$$C = 2\pi\varepsilon_0\varepsilon_r * \frac{(R * r)}{(R - r)} -------------- (7)$$

Where, R- internal radius of conductor, r- external radius of enclosure

II. Mitigation of Very Fast Transient Over Voltages

A. Shunt Resistor (Rsh) and Metal Oxide Surge Arrester (MO). In this research work, initially, no damping has been employed and the actual magnitude of very fast transient over voltages (Very fast transient over voltages (VFTOs)[2,12] at transformer, open end and at disconnecting switch have been used and in the process of mitigation shunt resistor method and surge arrester methods are employed for mitigation of very fast transient over voltages at transformer, open end and at disconnecting switch (DS) [4, 11] .The MOA in the proposed system has been designed on the basis of very fast transient with capacitance of 2000pF, 63ohm on each side of GIS .

B. Terminal Components (OHTL & Cable)

In the next stage of this research work, the gas insulated substation (GIS) has been terminated with over head transmission line and XLPE cable, the OHTL and cable parameters are estimated based on surge impedance (Z_0) and propagation velocity ($\boldsymbol{\upsilon}$) with the equations (1) and (2).The parameters used shown below. For OHTL, Z_0 = 350Ω, $\boldsymbol{\upsilon}$ =300m/µs, MOA, = 2000pf with ground resistance of 0.1Ωand for Cable, Z_0 = 30Ω, $\boldsymbol{\upsilon}$ = 1.9557X10^5 km/s. The very fast transient over voltages (VFTOs) at transformer (V_{tr}), open end (V_{oc}) and at disconnecting switch (V_{ds}) have been estimated.

III. Test Results of Proposed System

A. Test Results without Damping

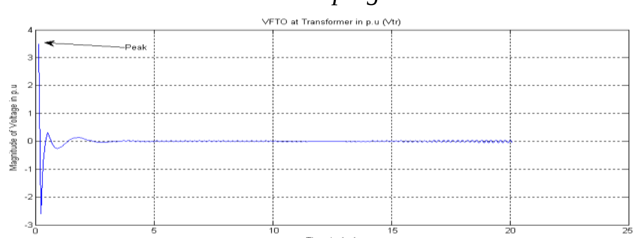

Fig.1. Magnitude of VFTO at Transformer (V_{tr})

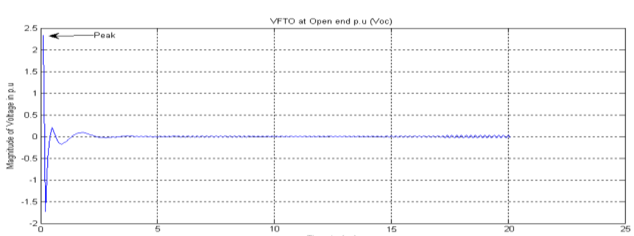

Fig.2. Magnitude of VFTO at Open end (V_{oc})

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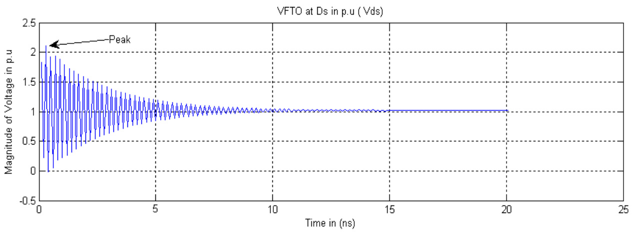

Fig.3. Magnitude of VFTO at disconnecting switch (DS)

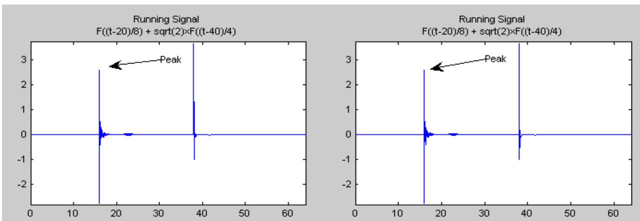

Fig.4. Magnitude of VFTO at Transformer (V_{tr}) Db4

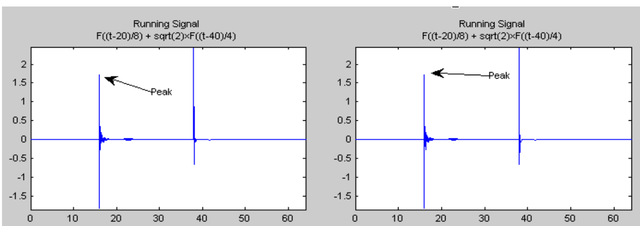

Fig.5. Magnitude of VFTO at open end (V_{oc}) Db4

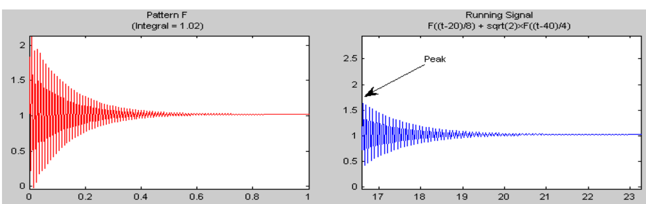

Fig.6.Magnitude of VFTO at disconnecting switch (V_{ds}) Db4

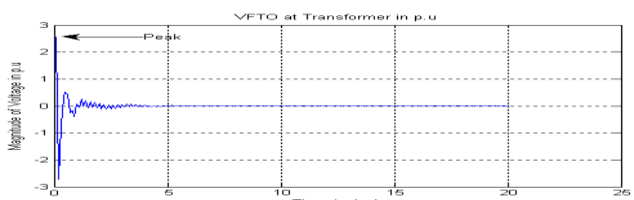

Fig.7. Magnitude of VFTO at Transformer (V_{tr})

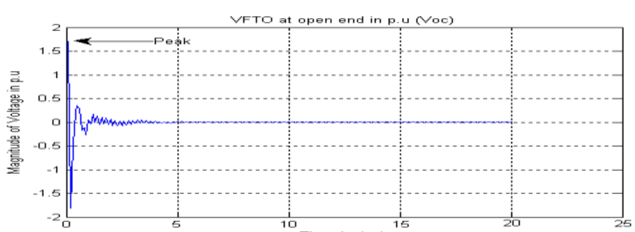

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Fig.8. Magnitude of VFTO at open end (V_{oc})

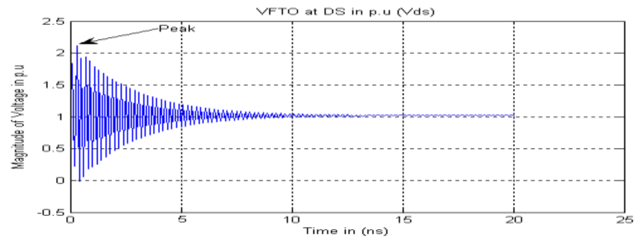

Fig.9. Magnitude of VFTO at disconnecting switch (V_{ds})

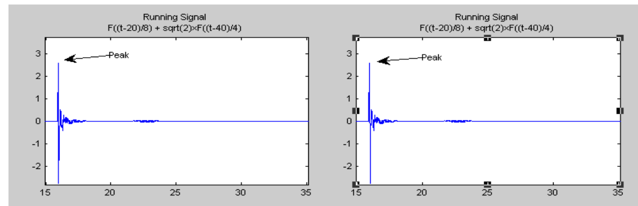

Fig.10. Magnitude of VFTO at Transformer (V_{tr}) Db4

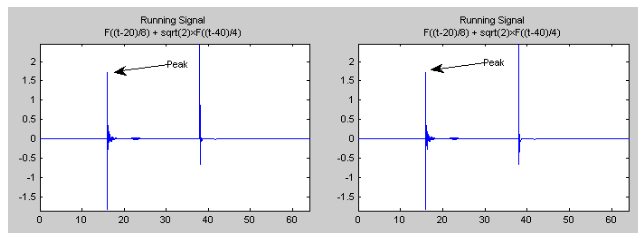

Fig.11. Magnitude of VFTO at open end (V_{oc}) Db4

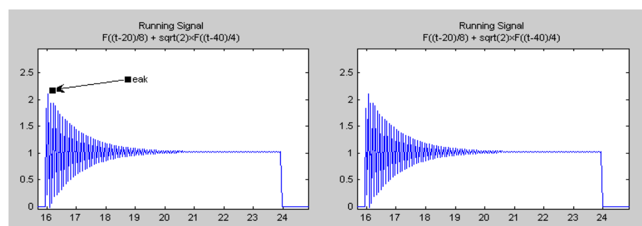

Fig.12. Magnitude of VFTO at disconnecting switch (V_{ds}) Db4

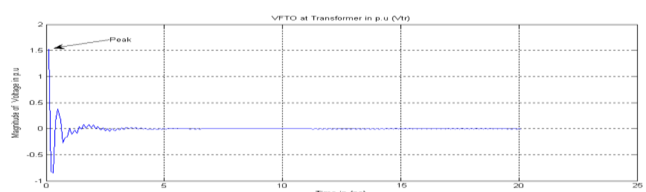

Fig.13. Magnitude of VFTO at Transformer (V_{tr})

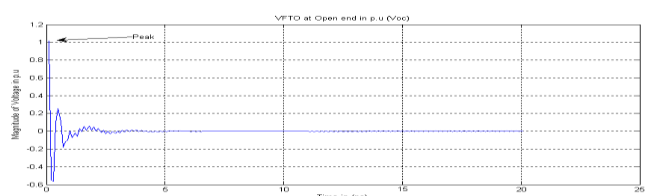

Fig.14. Magnitude of VFTO at Transformer (V_{oc})

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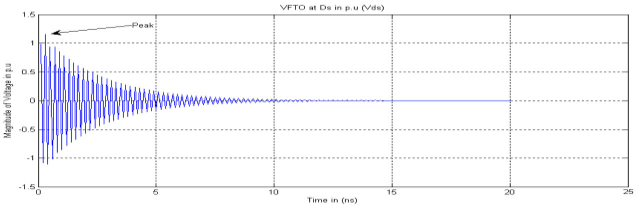

Fig.15. Magnitude of VFTO at Transformer (V_{ds})

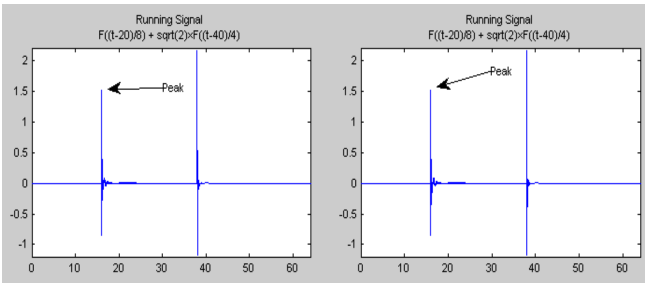

Fig.16. Magnitude of VFTO at Transformer (V_{tr}) Db4

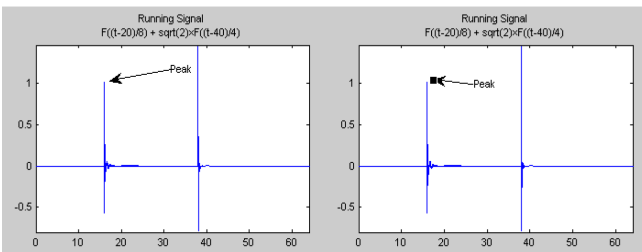

Fig.17. Magnitude of VFTO at Transformer (V_{oc}) Db4

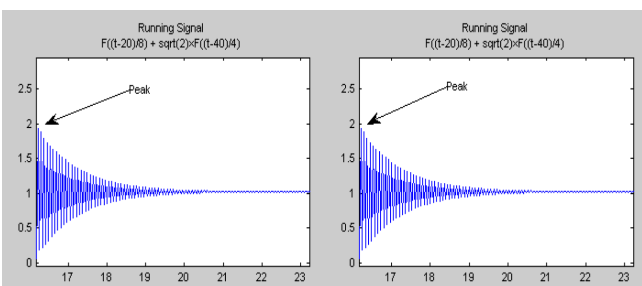

Fig.18. Magnitude of VFTO at Transformer (V_{ds}) Db4

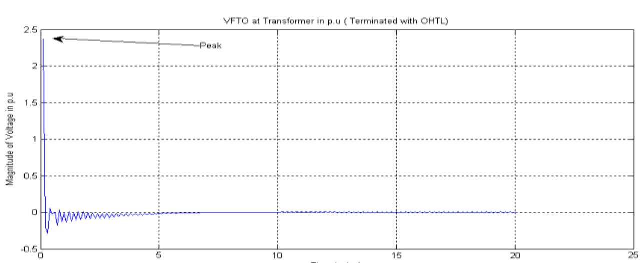

Fig.19. Magnitude of VFTO at Transformer (V_{tr})

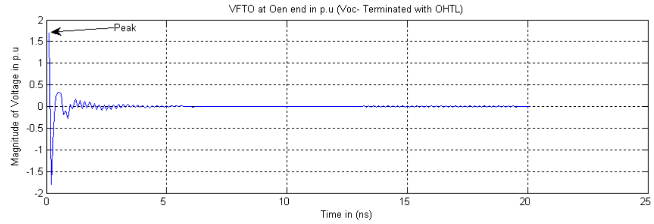

Fig.20. Magnitude of VFTO at open end (V_{oc})

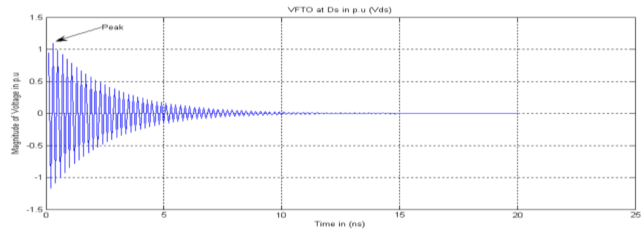

Fig.21. Magnitude of VFTO at disconnecting switch (V_{ds})

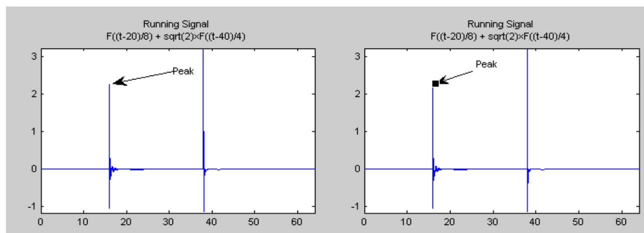

Fig.22. Magnitude of VFTO at Transformer (V_{tr}) Db4

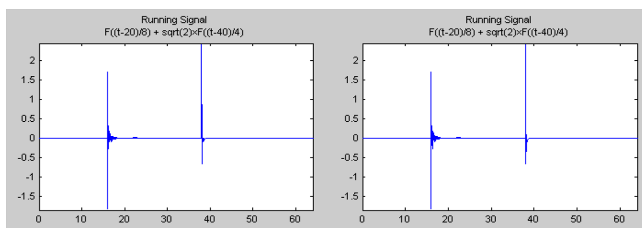

Fig.23. Magnitude of VFTO at open end (V_{oc})

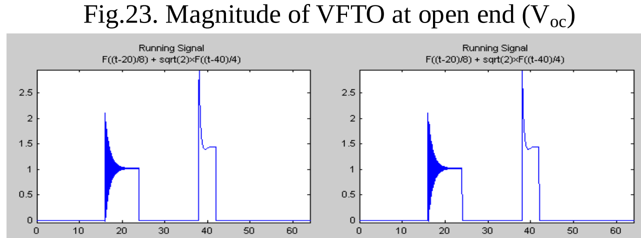

Fig.24. Magnitude of VFTO at open end (V_{ds})

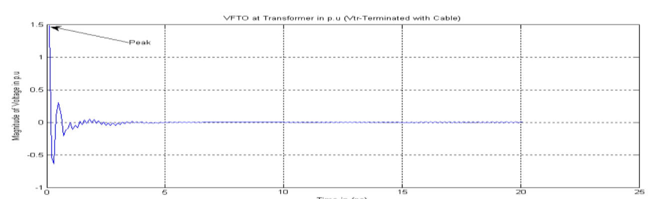

Fig.25. Magnitude of VFTO at transformer (V_{tr})

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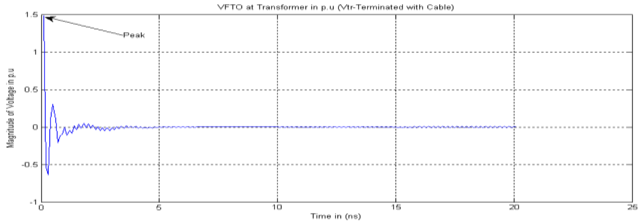

Fig.26. Magnitude of VFTO at open end (V_{oc})

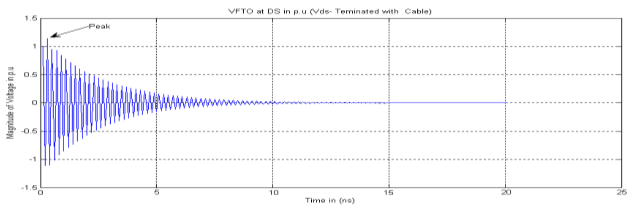

Fig.27. Magnitude of VFTO at disconnecting switch (V_{ds})

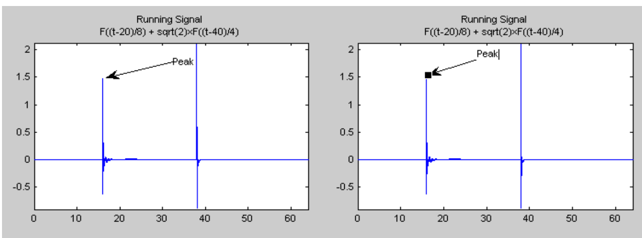

Fig.28. Magnitude of VFTO at Transformer (V_{tr}) Db4

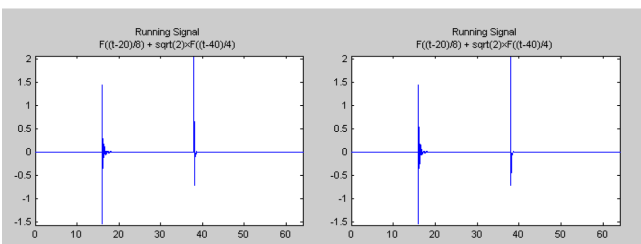

Fig.29. Magnitude of VFTO at open end (V_{oc})

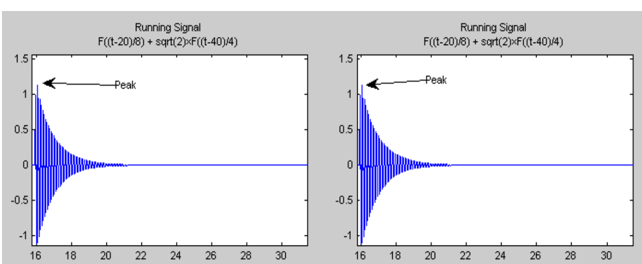

Fig.30. Magnitude of VFTO at open end (V_{ds})

IV. RESULTS AND DISCUSSIONS

From the table I following observations can be inferred. At first the framework has been reproduced without utilizing any damping and result have and are appeared in figures from 1, 2 and 3. The results of wavelet transform (WT) (Db4) appeared in figure 4, 5 and 6.In the following phase of this work shunt resistor technique has been executed and the mimicked results are appeared in figures 7, 8 and 9 and the results of wavelet transform (WT) appeared in figures 10, 11 and 12. In the second phase of this simulation work, MOA damping strategy has been utilized and the out happens to this strategy are appeared from figures 13, 14, 15 and wavelet results are from figures 16, 17 and 18. In the following period of this work over head transmission line with time of developmental time steady of **τ** = 1.0ns has been ended with gas protected substation and the framework has been tried for Very fast transient over voltages (VFTOs), the outcomes are appeared in figures 19, 20 and 21, with wavelet transform (WT)(Db4) figures 22, 23 and 24 again XLPE link has been terminated and the reproduced results are appeared in figures from 25, 26 and 27 and in addition the wavelet transform (WT)(Db4) appeared in figures 28, 29 and 30.The evaluated estimations of very fast transient over voltages (Very fast transient over voltages (VFTOs) at transformer, open end and disconnectors (DS) is organized in table 1.The wavelet transform (WT) based estimations of the same is appeared in the same table and there we can have the examination in the middle of with and without wavelet transform. By this exploration work it can be inferred that estimation of Very fast transient over voltages (VFTOs) is essential progressively that an accurate estimation and estimation of Very fast transient

TABLE I. PEAK VALUES OF VFTO IN P.U (V_{TR}, V_{OC} AND V_{DS} (TR-TRANSFORMER, OC-OPEN END AND DS-DISCONNECTOR)

	Method	V(tr) (p.u)	V(oc) (p.u)	V(ds) (p.u)
No-Damp	Direct	3.28	2.28	2.12
	Db4	2.79	1.88	1.65
Shunt R	Direct	2.69	1.74	2.10
	Db4	2.65	1.68	2.09
MOA	Direct	1.52	1.01	1.24
	Db4	1.51	1.01	1.98
OHTL	Direct	2.43	1.72	2.21
	Db4	1.79	1.69	2.18
CABLE	Direct	1.49	1.48	1.16
	Db4	1.52	1.47	1.21

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over voltages (VFTOs) is critical. From the outcomes it is again demonstrated that correct and precise crest estimations of Very fast transient over voltages (VFTOs) can be accomplished by the use of wavelet transform (WT) (Db4). A percentage of the critical have been seen from the results.

V. CONCLUSIONS

The proposed system765kV/400kV has been outlined and reproduced for Very fast transient over voltages (VFTOs) at better places utilizing Mat Lab platform. A percentage of the huge results have been seen from the results a takes after

a) The crest greatness of Very fast transient over voltages (VFTOs) can be decreased to certain level by shunt resistor however the steepness of the wave can't be lessened to significant level which can be seen from figure 6.Compared to shunt resistor technique to the more degree the size of Very fast transient over voltages (VFTOs) can be diminished further by utilizing metal oxide surge arrester (MOA) which can be seen from table1 (extent of Very fast transient over voltages (VFTOs) with shunt R is 2.108p.u with MOA it is 1.24p.u, however the steepness of Very fast transient over voltages (VFTOs) still present which implies we can comprehend that the metal oxide surge arrester (MOA) can't respond to Very fast transient over voltages (VFTOs) with enough speed.

b) The peak magnitude of Very fast transient over voltages (VFTOs) at transformer and at open end has decreased to significant level by metal oxide surge arrester (MOA) contrasted with shunt resistor.

c) Finally, metal oxide surge arrester (MOA) strategy can be proffered for relief of Very fast transient over voltages (VFTOs) at transformer and at open end, not best at DS. The link end decreases the crest level of Very fast transient over voltages (VFTOs) at transformer, open end and also at separating switch when contrasting and the OHTL.

d) The smaller than normal Very fast transient over voltages (VFTOs) found by metal oxide surge arrester (MOA) at open end (1.01p.u) and the scaled down Very fast transient over voltages (VFTOs) found at transformer by link (1.495p.u). This simulation work demonstrates again that the wavelet transform (WT) change gives precise consequences of top estimations of Very fast transient over voltages (VFTOs).

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