Analysis of Very Fast Transient over Voltages in 150MVA 500KV Transformer by Using Wavelet Transform

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Abstract: ***This paper deals with analysis of VFTOs (Very Fast Transient over Voltages) in transformer, in this work the 150MVA, 500KV power transformer is considered and is designed by using MATLAB software of version 7. Very fast transient over voltages (VFTOs) generated by operating disconnections in gas insulated switch gear (GIS) could cause dielectric and mechanical stress and voltage oscillation inside the transformer connected. The situation is severer in the system that the main transformer is directly connected to GIS since the high frequency surges travel more easily along the coaxial gas insulated bus. The VFTOs in transformer windings have always been troublesome therefore it is important to analyze the wave both in time domain and frequency domain, therefore the wavelet transform is implemented. There are several works on vftos carried by many authors, but this method is efficient and can be used to compute the effect of VFTOs in transformer there by necessary methods of suppression can be implemented to reduce the effect of very fast transient over voltages in the transformer***

Keywords: VFTOs, Mat lab, Wavelet, Transformer, Switching, surges,

1. Introduction

In modern power systems Gas insulated substation (GIS) has gained a wide range of acceptance due to its compactness and high reliability. Switching operations of dis-connector switch and circuit breaker within GIS generates very fast transient over voltages (VFTOs), which are characterized by a very short rise-time of less than 0.1 μs and amplitude of 2.5 p.u. and an oscillatory component of several MHz lasting for tens of micro seconds [1-2]. The Very Fast Transient Over Voltages could cause oscillations in the voltage inside the transformer connected directly to GIS, since high frequency surges travel more easily along the coaxial gas insulated bus. Resonance may occur in transformer winding when the frequency of incoming VFTO matches some of the resonant frequencies of the transformer [2]. it can unbalance in the voltage distribution cause an unbalance in voltage distribution in transformer windings due to its short time nature. Under these circumstances, the turn-to-turn voltage can rise close to the transformer basic insulation level. The VFTOs produced by switching in GIS depends on connections between the transformer and GIS as well as type of transformer and the parameters used for the design of transformer [5].

2. Wavelet Transform

The wavelet transform is similar to the Fourier transform (or much more to the windowed Fourier transform) with a completely different merit function. The main difference is this: Fourier transform decomposes the signal into sines and cosines, i.e. the functions localized in Fourier space; in contrary the wavelet transform uses functions that are localized in both the real and Fourier space. Generally, the wavelet transform can be expressed by the following equation:

$$F(a,b) = \int_{-\infty}^{\infty} f(x)\, \psi^{*}_{(a,b)}(x)\, \mathrm{d}x \qquad (1)$$

Where the * is the complex conjugate symbol and function ψ is some function. This function can be chosen arbitrarily provided that obeys certain rules. As it is seen, the Wavelet transform is in fact an infinite set of various transforms, depending on the merit function used for its computation. This is the main reason, why we can hear the term "wavelet transforms" in very different situations and applications. There are also many ways how to sort the types of the wavelet transforms. Here we show only the division based on the wavelet orthogonality. We can use *orthogonal wavelets* for discrete wavelet transform development and *non-orthogonal wavelets* for continuous wavelet transform development. These two transforms have the following properties:

The discrete wavelet transform returns a data vector of the same length as the input is. Usually, even in this vector many data are almost zero. This corresponds to the fact that it decomposes into a set of wavelets (functions) that are orthogonal to its translations and scaling. Therefore we decompose such a signal to a same or lower number of the wavelet coefficient spectrum as is the number of signal data points. Such a wavelet spectrum is very good for signal processing and compression, for example, as we get no redundant information here. The continuous wavelet transforms in contrary returns an array one dimension larger thatn the input data. For a 1D data we obtain an image of the time-frequency plane. We can easily see the signal frequencies evolution during the duration of the signal and compare the spectrum with other signals spectra. As here is used the non-orthogonal set of wavelets, data are correlated highly, so big redundancy is seen here. This helps to see the results in a more humane form.

2.1 Discrete Wavelet Transform

The discrete wavelet transform (DWT) is an implementation of the wavelet transform using a discrete set of the wavelet scales and translations obeying some defined rules. In other words, this transform decomposes the signal into mutually orthogonal set of wavelets, which is the main difference from the continuous wavelet transform (CWT), or its implementation for the discrete time series sometimes called discrete-time continuous wavelet transform (DT-CWT). The wavelet can be constructed from a scaling function which describes its scaling properties. The restriction that the scaling functions must be orthogonal to its discrete translations implies some mathematical conditions on them which are mentioned everywhere, e.g. the dilation equation

$$\varphi(x) = \sum_{k=-\infty}^{\infty} ak\varphi(Sx - K) \quad (2)$$

Where S is a scaling factor (usually chosen as 2). Moreover, the area between the function must be normalized and scaling function must be orthogonal to its integer translations, i.e.

$$\int_{-\infty}^{\infty} \phi(x)\, \phi(x+l)\, \mathrm{d}x = \delta_{0,l} \quad (3)$$

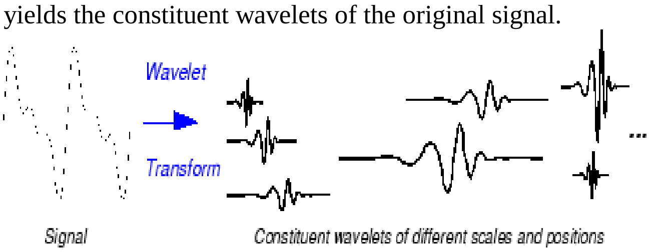
After introducing some more conditions (as the restrictions above does not produce unique solution) we can obtain results of all these equations, i.e. the finite set of coefficients a_k that define the scaling function and also the wavelet. The wavelet is obtained from the scaling function as N where N is an even integer.The set of wavelets then forms an orthonormal basis which we use to decompose the signal. Note that usually only few of the coefficients a_k are nonzero, which simplifies the calculations.

2.2 Continuous Wavelet Transform

Like the Fourier transform, the continuous wavelet transform (CWT) uses inner products to measure the similarity between a signal and an analyzing function. In the Fourier transform, the analyzing functions are complex exponentials; $e^{j\omega t}$ The resulting transform is a function of a single variable, ω. In the short-time Fourier transform, the analyzing functions are windowed complex exponentials, W (t) $e^{j\omega t}$ and the result in a function of two variables.The STFT coefficients, F(ω,τ) represent the match between the signal and a sinusoid with angular frequency ω in an interval of a specified length centered at τ.In the CWT, the analyzing function is a wavelet, ψ. The CWT compares the signal to shifted and compressed or stretched versions of a wavelet. Stretching or compressing a function is collectively referred to as dilation or scaling and corresponds to the physical notion of *scale*. By comparing the signal to the wavelet at various scales and positions, you obtain a function of two variables. The two-dimensional representation of a one-dimensional signal is redundant. If the wavelet is complex-valued, the CWT is a complex-valued function of scale and position. If the signal is real-valued, the CWT is a real-valued function of scale and position. For a scale parameter, a>0, and position, *b*, the CWT is:

$$C(a,b;f(t),\psi(t)) = \int_{-\infty}^{\infty} f(t)\frac{1}{\sqrt{a}}\,\psi*\frac{(t-b)}{a}\,dt \quad (4)$$

where * denotes the complex conjugate. Not only do the values of scale and position affect the CWT coefficients, the choice of wavelet also affects the values of the coefficients. By continuously varying the values of the scale parameter, *a*, and the position parameter, *b*, you obtain the *CWT Coefficients C(a,b).* Note that for convenience, the dependence of the CWT coefficients on the function and analyzing wavelet has been suppressed. Multiplying each coefficient by the appropriately scaled and shifted wavelet yields the constituent wavelets of the original signal.



There are many different admissible wavelets that can be used in the CWT. While it may seem confusing that there are so many choices for the analyzing wavelet, it is actually strength of wavelet analysis. Depending on what signal features you are trying to detect, you are free to select a wavelet that facilitates your detection of that feature. For example, if you are trying to detect abrupt discontinuities in your signal, you may choose one wavelet. On the other hand, if you are interesting in finding oscillations with smooth onsets and offsets, you are free to choose a wavelet that more closely matches that behavior.

3. Generation of Very Fast Transient over Voltages (VFTOs):

During the switching operation of dis-connector switch in a GIS, re- strikes (pre-strikes) occur because of the low speed of the dis-connector switch moving contact, due to the very fast voltage collapse within a few nano seconds(ns) and the subsequent traveling waves, Very Fast Transient Over-voltages are developed. The main oscillation frequency of the fast transients depends on the configuration [8]. Moreover, the effect of complexity of the configuration of a on the peak value of the transients has been studied in this thesis. For the development of equivalent circuits, step response measurements of the main components have been made. Using the MMATLAB the equivalent electrical models are developed. The peak value of the fast transients often occurs when circuit structure is relatively simple, but more frequently if the structure is rather complicated. The propagation velocity of traveling wave generated during dis-connector switch operation is about 30cm/ns. 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

4. Modeling and simulation of VFTOs

In this paper 150MVA, 500KV transformer is designed by using mat lab software with the version of 7.0.The disconnectors are connected on both the sides of the transformer in ordered to get switching conditions and is shown in fig1 the disconnector is represented by a PI section comprises of two travelling wave models , two capacitors to grouns and a capacitor across the the breaker contacts as shown in figure.1 and A circuit breaker is represented by a PI circuit with five travelling wave models and four capacitors and is shown in figure 2.a.Dute to switching operation the generated transient over voltages between each phase of the transformer has been extracted and are analyzed by using wavelet transform. The daubechies wavelet level4 (Db4) is used to analyze the transient over voltages generated by the switching at the transformer.

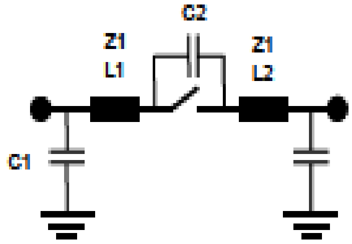


Figure 1: Disconnector

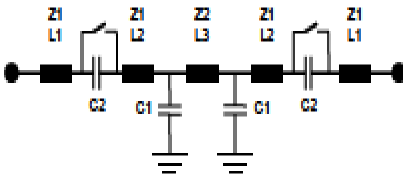


Figure 2: Circuit Breaker

Table 1: Parameters of Dis-connector and Circuit Breaker:

Sno	*Name of the device*	*Parameters*
1	**Dis-connector**	Z1 = 35Ω L1 = 640mm L2 = 450mm C1 = 25µF C2 =25 µF
2	**Circuit Breaker**	Z1 = 58Ω L1 = 560mm L2 = 930mm Z2 = 16Ω L3 = 400mm C1 = 20 µF C2 = 420 µF

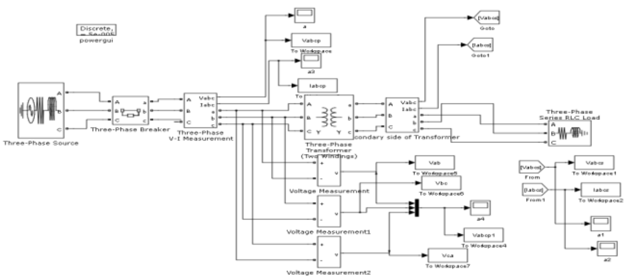


Figure 3: Mat Lab simulink moel of 150MVA, 500kv Transformer

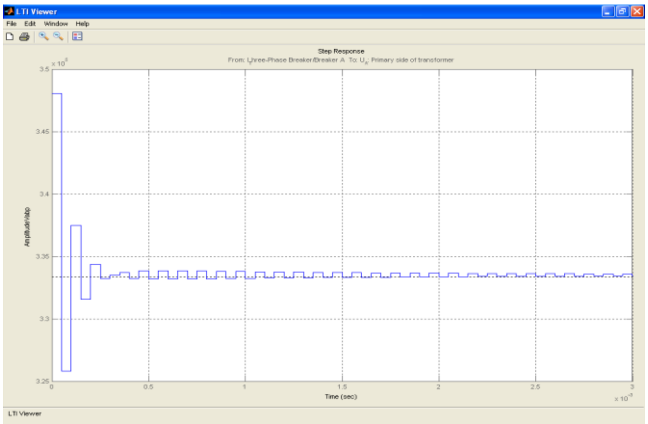


Figure 4: phase voltage Vabc

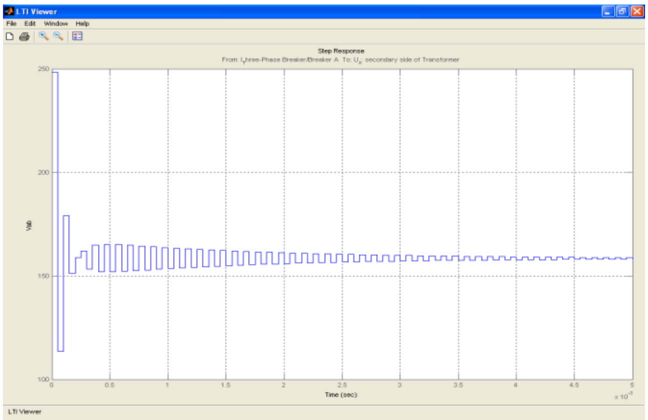


Figure 5: Phase voltage Vab

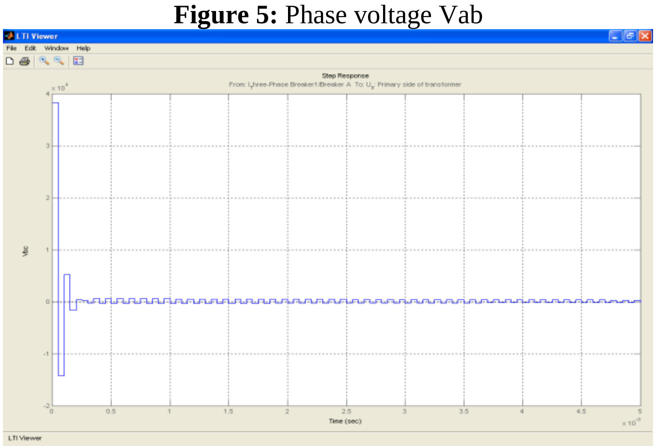


Figure 6: Phase voltage Vbc

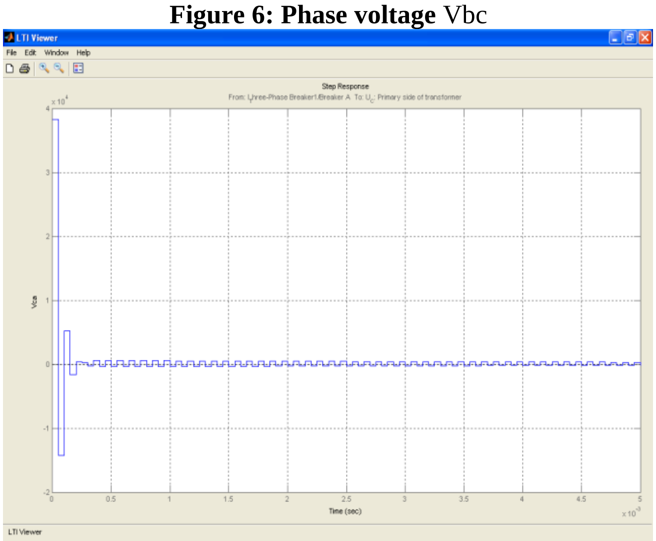


Figure7: Phase voltage Vca

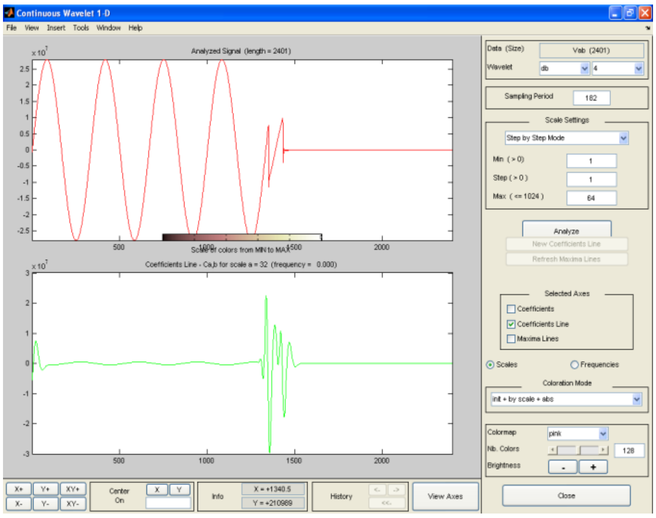


Figure 8: Phase voltage of Vab by wavelet transform

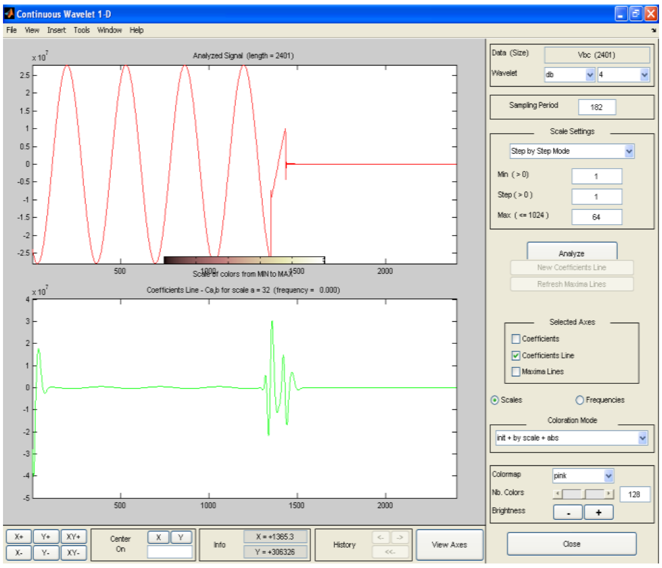


Figure 9: Phase voltage of by wavelet transform Vbc

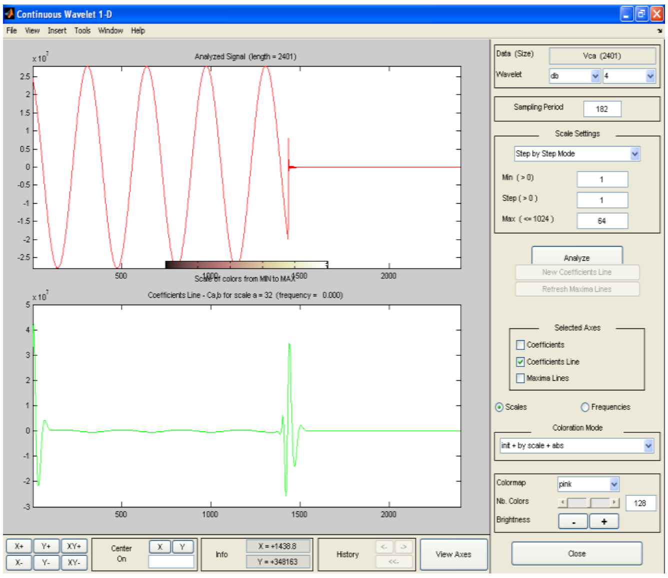


Figure 10: Phase voltage of by wavelet transforms Vca

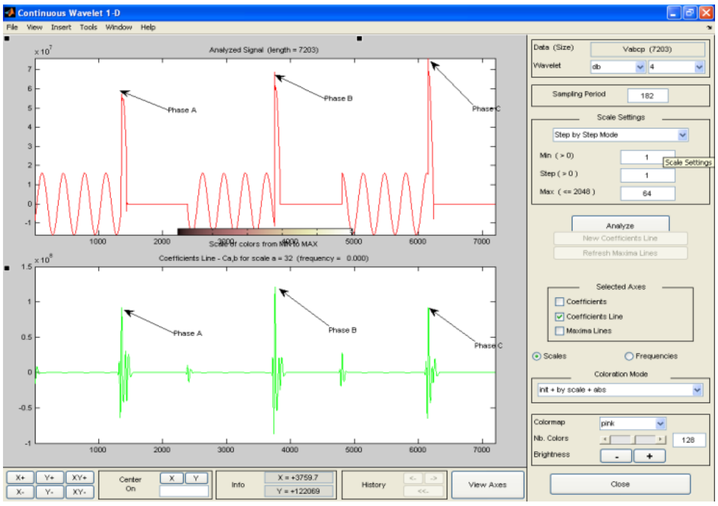


Figure 11: Three Phase voltage on Primary side of the transformer by wavelet transform Vabc

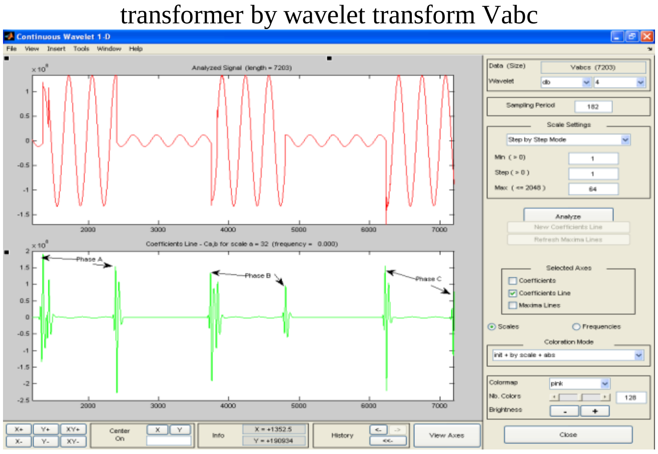


Figure 12: Three Phase voltage on secondary side of the transformer by wavelet transform Vabc

5. Results and Conclusions

In this paper a 150MVA, 500KV transformer is considered and its simulink model is developed using mat lab software with the version of 7.0.The disconnectors and circuit breakers are designed with the parameters as shown in table 1.The key elements of the modelling methodology are described along with typical simulation results and the principle conclusions drawn from the analysis. The step response of vftos are shown in figures 4,5,6 and 7 which are analysed by LTI viewer The vftos are analyzed by the wavelet transform for three phase primary and secondary side of the transformer and are shown in figure 11 and 12 as well as the vftos are analyzed for Vab,Vbc and Vca and are shown in figure 8,9 and 10.It is observed that the vftos analyzed by the wavelet transform gives the better and almost exact peak value of the vftos as compared to the conventional methods. By this paper it can be easily estimate the peak value of vftos and there by the required and suitable methods can be chosen for suppression of vftos at the transformer.

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