APPLICATION OF WAVELET TRANSFORMS FOR ALTERNATOR STATOR FAULT LOCATION AND PROTECTION

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ABSTRACT

This paper presents the novel approach in protection and detection techniques of Alternator stator winding from the earth faults which are simulated between 2% to 10% distance point from the alternator neutral, since the impedence at that distance is very high we can not detect or protect by normal methods. The transient produced is analyzed in discreet Wavelet transforms. The potential of using discreet wavelet transforms in protection relay is examined and model of relay using transient phenomenon to fault in the winding in alternator stator is proposed and next integrated into ATP integration program.

Keywords: *Wavelet Transforms, Faults, Fault Transient, Digital Relay, And Arc Model.*

1. INTRODUCTION

Synchronous generators are important elements of a power system. Its reliability and proper functioning are crucial in maintaining an uninterrupted power supply to the customers. A lot of attention has been focused on generator's single phase to ground fault [19, 20] which is one of the main causes for shutting down a generator. Stator's winding fault must be avoided since the amount of time wasted and the cost for repairing a generator is enormous. Hence, it is necessary to prevent such occurrences by incorporating reliable protection and monitoring schemes [1], [3]-[7]. Besides monitoring the deterioration of generator stator windings, it is advisable to incorporate some advance signal processing tools to handle and analyze the complex transient phenomena in today's interconnected electrical environment [15, 17, 21, 23, 25]. New methods, based on wavelet theory, emerged in recent years to analyze transient occurrences are examples to overcome the limitations of the traditional tools [2, 24], [8-14].

From that moment, there has been a great research progress in the development of digital protection techniques. Moreover, the digital protection algorithm has been applied to almost every area of power system protection [2, 17]. With the development of micro-electronic technology, the computational power of microprocessors and Digital Signal Processors (DSP) has been greatly increased and the costs have reduced. It is now realized that the time for the development of cost effective protection for the power system is coming. At the same time recent developments in power system protection have provided new relaying principles suitable for distribution system protection [16,18,22]. In particular, the newly developed transient directional relay [25] and transient directional comparison scheme do not require the voltage transducer. It will be a great step in power system protection if the techniques can be successfully applied in this area [26].

Normally, a power system operates under balanced conditions. Under abnormal, that is, fault conditions, the system may become unbalanced, if the insulation difference come in contact with each other, a short-circuit, or fault, is said to occur. The contact may be a physical metallic one, or it may occur through an arc.

A fault may occur on a power system due to a number of reasons. Some of the common causes have their origins in natural disturbances like lightning, high-speed winds, earthquakes, earth tremors, snow, frost etc. Generators, transformers, and other protective switchgear may fail due to insulation breakdown. There may be accidental faults such as falling of a tree along a line, vehicles colliding with supporting structures, airplane crashing with the line, birds shorting line. Sometimes sabotage also results in creating faults. Contamination of insulators may also result in a fault. Wind and ice loading may cause insulator strings to fail mechanically. Deterioration of insulation due to ageing and over loading of underground cables results in short circuits. Sometimes small animals like rats, lizards, etc. enter switchgear to create faults.

Faults may occur at different points in a power system. However, here we will be mostly concerned with faults on transmission lines.

2. WAVELET TRANSFORMS

The wavelet transform or wavelet analysis is probably the most recent solution to overcome the shortcomings of the Fourier transform. In wavelet analysis the use of a fully scalable modulated window solves the signal-cutting problem. The window is shifted along the signal and for every position the spectrum is calculated. Then this process is repeated many times with a slightly shorter (or longer) window for every new cycle. In the end the result will be a collection of time-frequency representations of the signal, all with different resolutions. Because of this collection of representations we can speak of a multi resolution analysis. In the case of wavelets we normally do not speak about time-frequency representations but about time-scale representations, scale being in a way the opposite of frequency, because the term frequency is reserved for the Fourier transform.

The Wavelet transform provides a time-frequency representation of the signal. It was developed to overcome the short coming of the Short Time Fourier transform (STFT), which can also be used to analyze non-stationary signals. While STFT gives a constant resolution at all frequencies, the Wavelet transform uses multi-resolution technique by which different frequency spectrums are analyzed with different resolutions [10].

A wave is an oscillating function of time or space and is periodic. In contrast, wavelets are localized waves. They have their energy concentrated in time or space and are suited to analysis of transient signals. While Fourier transform and STFT use waves to analyze signals, the Wavelet Transform uses wavelets of finite energy [27].

2.1 Symlet wavelets

In *symN*, *N* is the order. Some author's use 2*N* instead of *N*. Symlets is only near symmetric; consequently some authors do not call them symlets. More about symlets can be found in [Dau92], pages 194, 254-257. By typing wave info ('sym') at the MATLAB command prompt, you can obtain a survey of the main properties of this family.

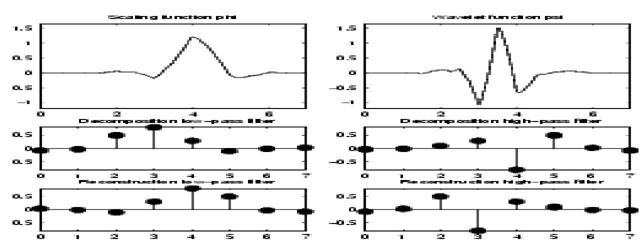


Fig 1: Symlets sym4

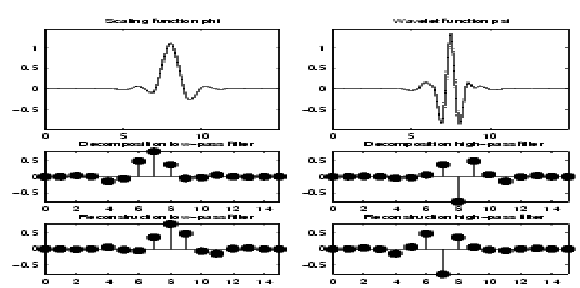


Fig 2: Symlets sym8

Daubechies proposes modifications of her wavelets that increase their symmetry can be increased while retaining great simplicity. The idea consists of reusing the function m_0 introduced in the *dbN*, considering the $|m_0(\omega)|^2$ as a function *W* of $z = e^{i\omega}$. Then we can factor *W* in several different ways in the form of $W(z) = U(z)\overline{U(\frac{1}{z})}$ because the roots of *W* with modulus not equal to 1 go in pairs. If one of the roots is z_1, then $\frac{1}{z_1}$ is also a root.

By selecting *U* such that the modulus of all its roots is strictly less than 1, we build Daubechies wavelets *dbN*. The *U* filter is a "minimum phase filter." By making another choice, we obtain more symmetrical filters; these are symlets. The symlets have other properties similar to those of the *dbN*s. Due to the property of symlet transforms when we go for analysation when fault occurs, the third peak of the obtained waveform reverses.

3. FAULT IDENTIFICATION

Using Wavelet transform analysis on the faulty phase current at the terminal of the generator, it can differentiate whether the fault is near the neutral point (less than 6% distance) of the generator or otherwise. This is done by detecting the 3rd peak of the Wavelet transforms. This has significant importance since conventional methods of differential protection can only provide protection in the order of about 90% of the windings. Currently, the above observations are being extended to different loading conditions which introduce harmonics and disturbances.

3.1 Digital relay

An over current relay is the simplest form of protective Relay which operates when the current in any circuit exceeds primary value .By using the Multiplexer and the Micro-processor can sense the fault current of the differential element of the circuits. If the value of magnitude of the third peak of the analyzed current waveform is less than zero then, the Micro-processor sends the tripping signal to the relay of the circuit.

As we know that the Micro-processor accepts signals in the form of voltage, the current signal derived from the current transformer is converted into a proportional voltage signal using current to voltage converter.

3.1.1 Algorithm

when the Micro processor is initialized it checks all the input output ports to initialize them then it checks for the open or closed condition of the circuit breaker if it is in open circuit condition the it keeps checking for closed condition, then it sends the signal to the multiplexer to switch on s1 to get the current in the line. Then it starts conversing the signal to ADC till the conversion is completed after the completion of conversion it reads the value of the line current. Now if the value of the current value is less than zero then it calls for the delay time for relay to operate and after the delay time it sends the signal to relay to trip. Otherwise it sends the signal to multiplexer to switch s2. The above process keeps on continuing. After the whole process is completed the Microprocessor jumps again to third step and checks for the Relay condition.

3.1.2 Flow chart

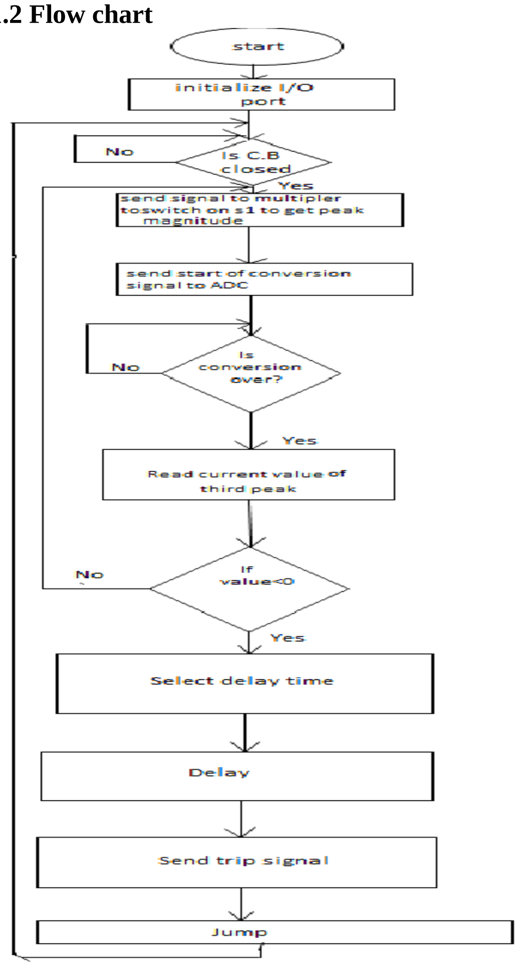


Fig 3: Flow chart

4. RESULTS

case 1 : off-load conditions

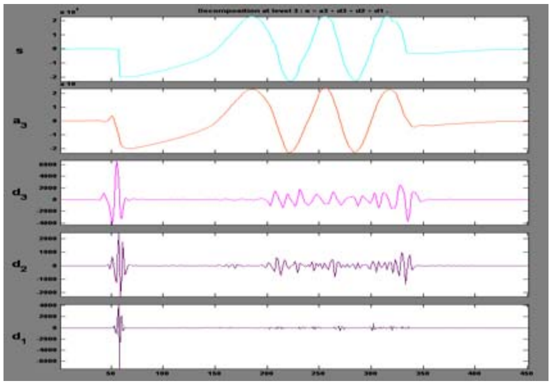


Fig 4 :At 4% of the distance

When a single phase to ground fault occurs, the measured terminal current waveform contains significant negative transient components. The faulted phase current (One faulted red phase is simulated) of 4%, 6%, 8% and 10% fault and its corresponding WT output at Detail Level 3 are plotted in figure 4, 5, 6 and7respectively

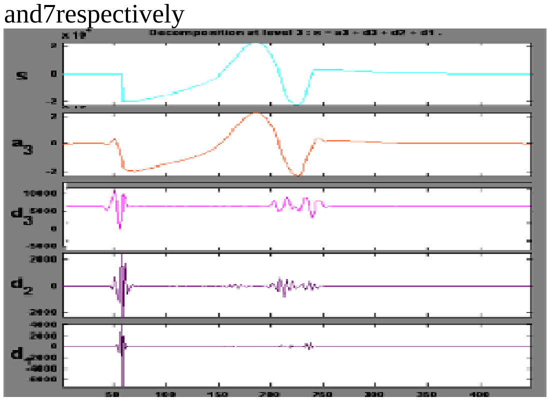


Fig 5: At 6% of the distance

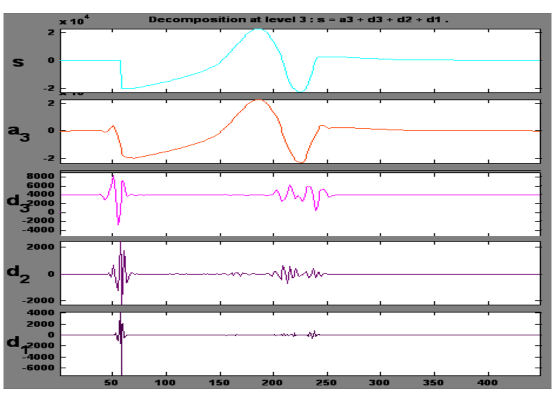


Fig 6: At 8% of the distance

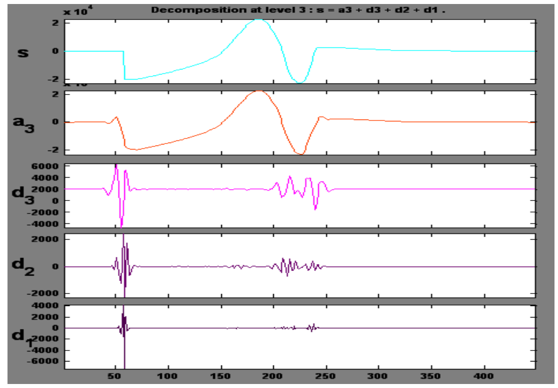


Fig 7: At 10% of the distance

Case 2: on load condition

Another power system model with additional load is simulated for comparison, and the same mother wavelet and decomposition level are chosen as per earlier simulation. The faulted terminal phase current waveforms with their respective Wavelet Transform are shown in figures 8, 9, 10 and11.

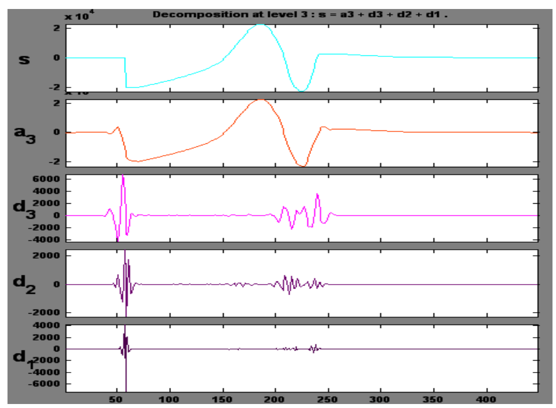


Fig 8: At 4% of the distance

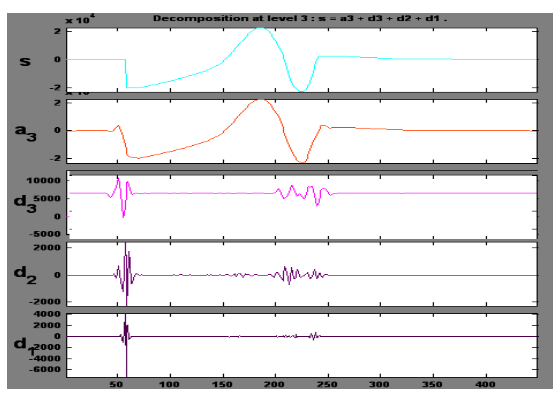


Fig 9: At 6%of the distance

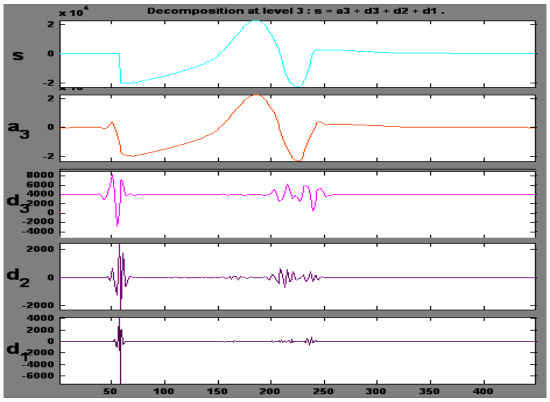


Fig 10: At 8% of the distance

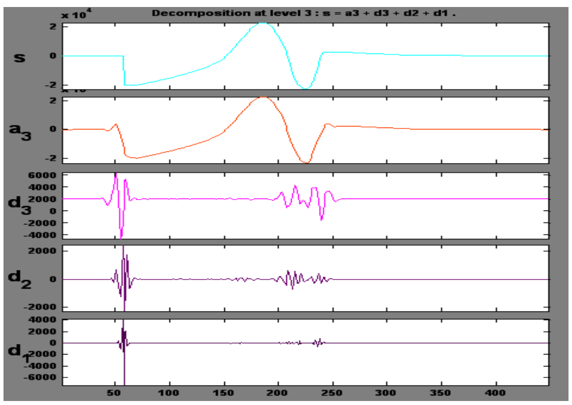
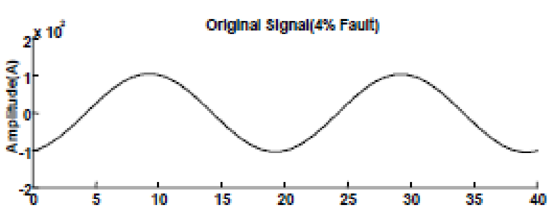


Fig 11: At 10% of the distance

4.1 EMTP Result

<u>Case 1:</u> Off load condition

Here the fig12, 13, 14 and 15 below shows the simulation results of the alternator stator windings at off load condition by using the EMTP software for the same fault simulated using MATLAB.



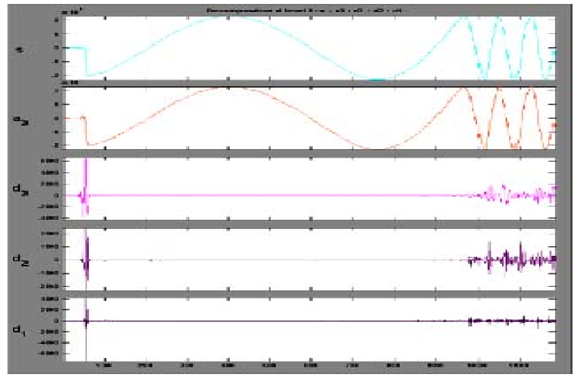
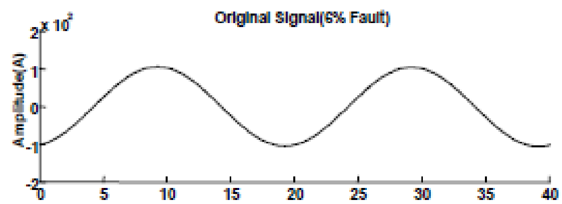


Fig 12: At 4% of the distance



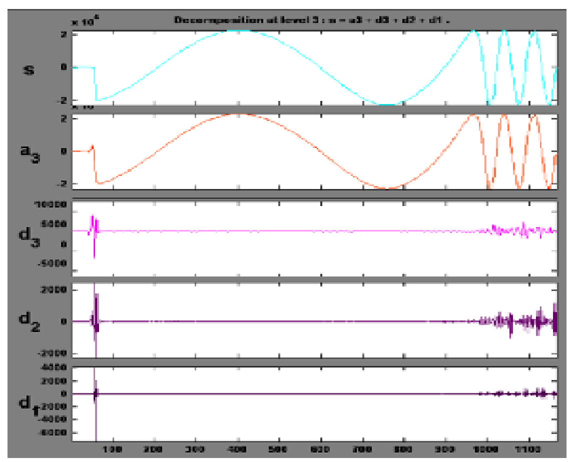
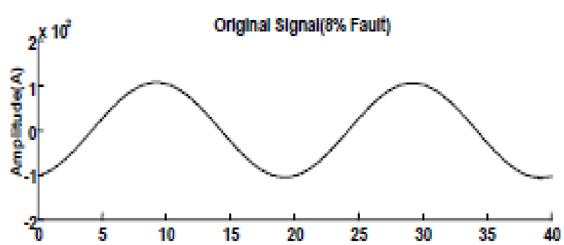


Fig 13: At 6% of the distance



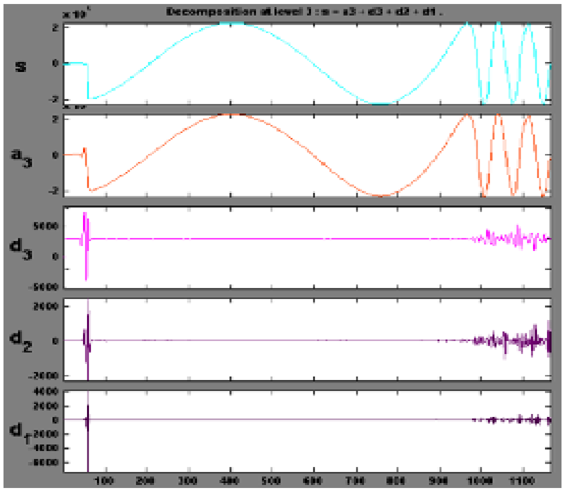
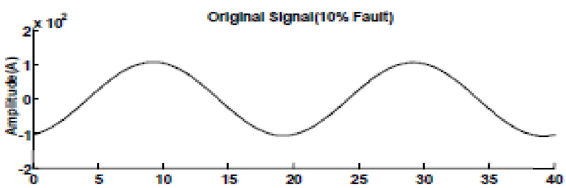


Fig 14: At 8% of the distance



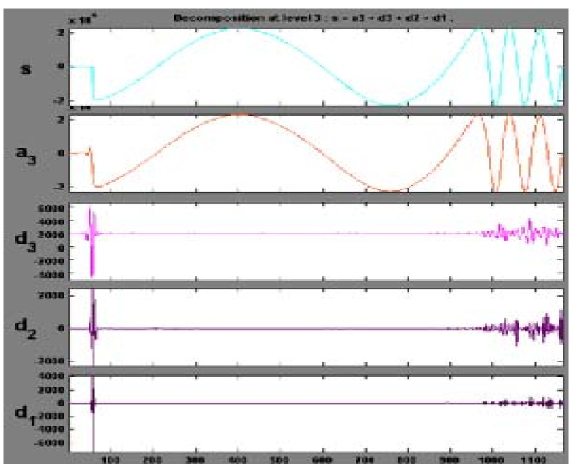
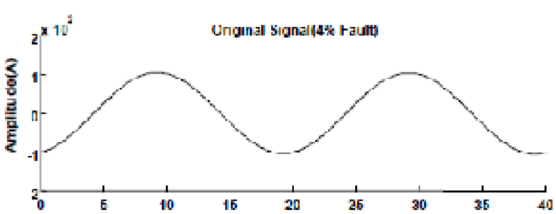


Fig 15: At 10% of the distance

Case2: On load Condition



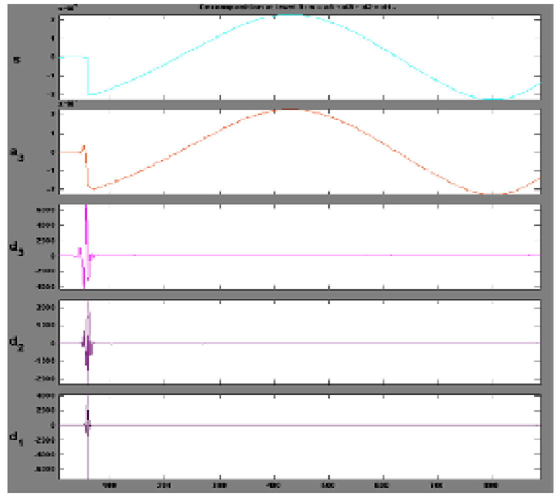
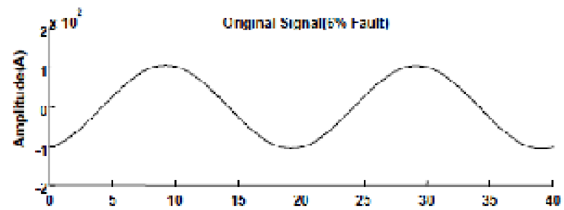


Fig 16: At 4% of the fault



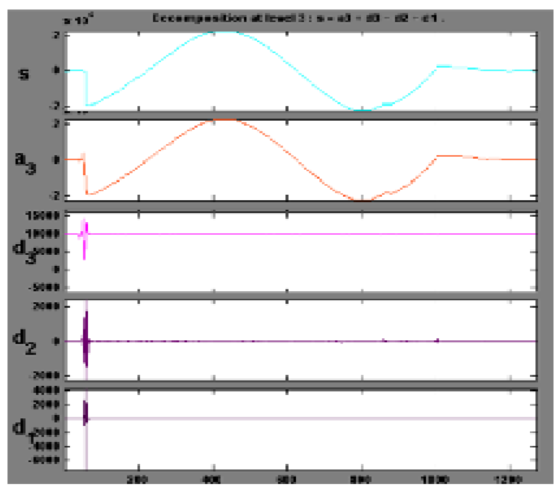
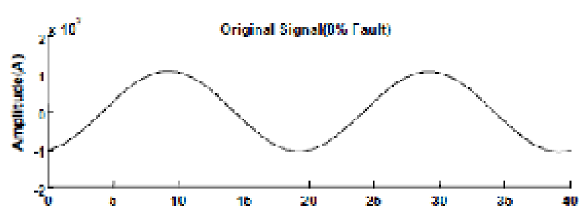


Fig 17: At 6% of the fault



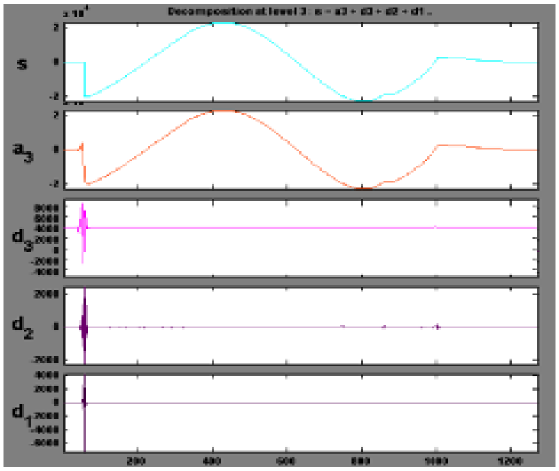


Fig 18: At 8% of the fault

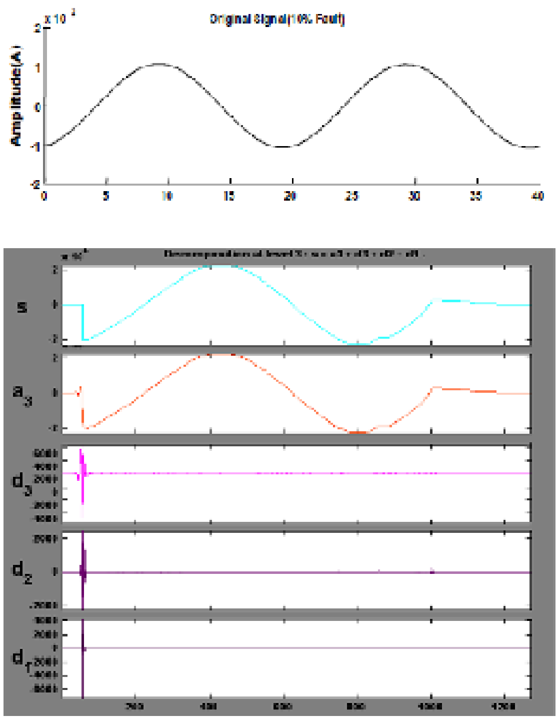


Fig 19: At 10% of the fault

Here the fig16, 17, 18 and 19 shows the simulation results of the alternator stator winding at on load condition by using EMTP software for the same fault simulated using MATLAB

4.2 Comparison

Here the simulations are performed in both the EMTP and MATLAB software's and both the results are analyzed using MATLAB and they are presented above. There may the difference in the waveforms but the results matches with desired outputs i.e; the third peak in both the analysations is same.

Some of the differences found in both the software's are:

S.No	EMTP	MATLAB
1	This is industrial software, used for industrial applications.	This is user friendly software, used for learning process.
2	This is real time application software.	This is user friendly software.
3	The availability is difficult.	It is easily available.
4	The expertise is required to use this software.	This is easy to use when compared to EMTP

5. CONCLUSION

A new method to differentiate the fault distance which occurs in the generator's stator windings is presented. Using Wavelet Transform analysis on the faulted phase current at the terminal of the generator, it can differentiate whether the fault is near the neutral point (less than 6% distance) of the generator or otherwise. This is done by detecting the 3rd peak of the WT. This has significant importance since conventional methods of differential protection can only provide protection in the order of about 90% of the windings. Currently, the above observations are being extended to different loading conditions which introduce harmonics and disturbances. A dynamic wavelet transform based approach for the generator protection based on micro processor operation is presented in this work. A simple and effective fault detecting and protecting approach based on Symlets wavelet transform is completed, and the comparison is provided.

This type of protection is more reliable and more accurate because the reference value of the wavelet transforms is zero.

In future we are trying to extend it to find the different faults that occur in the alternator and classify based on the transient occurred.

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