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A WAVELET BASED DIFFERENTIAL ALGORITHM FOR BUSBAR PROTECTION

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ABSTRACT

Busbar protection is an essential component in power system design, protecting the most important system node for network stability and security. When faults occurs on busbar itself, it takes much time to isolate the bus from source which may cause much damage in the bus system. Faults in power system are classified as internal and external faults. Faults within the zone are termed as internal faults whereas, the faults outside the Zone are called as external faults. Ideally, a relay looking after the protection of a zone should operate only for internal faults. It should restrain from operating for external faults or through faults. In this paper the busbar protection using differential protection scheme has been investigated for internal and external faults. An algorithm has been developed to improve the selectivity of the relay and the same has been tested in IEEE9 bus system for internal and external faults. Separation of De-noised signal from fault signal is made using wavelet transform so that the nature of fault occurs on the system can be identified. In this study Daubechies 4 at level 3 is used to separate original signal and de-noised signal. The entire simulation has been done using MATLAB R2017a.

Keywords: Busbar protection, Internal and external faults, Mother Wavelet, Works on busbar protection.

1. INTRODUCTION

The relay used in power system protection are of differential types. Among them differential relay is very usually used relay for protecting transformers and generators from localized faults. Differential relays are hypersensitive to the faults occurred within the zone. Most of the relays operate when any quality exceeds before a predetermined value for example over current relay operates when current through it compare predetermined value. But the principle of differential relay is rather different. It operates depending upon the difference between two or more similar. A differential relay is defined as the relay that operates when the phase difference of two or more identical electrical quantities exceeds a predetermined amount. The differential relay works on the principle of comparison between the point and magnitude of 2 or additional equivalent electrical quantities. Comparing 2 electrical quantities in a very circuit victimization differential relays is easy in application and positive in action.

Differential protection provides unit protection. The protected zone is strictly famous by the situation of current and potential transformers. The phase difference is achieved by suitable connections of secondary of CTs and PTs[5]. The differential protection principle is utilized for the protection of generator, generator-transformer units, transformers, feeders, giant motors, and bus-bars.

2. PROTECTION OF BUSBAR

2.1 BLOCKING LOGIC IN O\C RELAY

After limitations experienced with the use of over-current relays, dedicated busbar protection using numerical over-current relays with instantaneous protection and blocking logic are used to give a cost-effective and reliable result. This can also provide a discriminative phase and earth fault protection. The logic can be described as when there is a through the fault in any feeder, it will block the income to operate but when there is a busbar fault, the incomer breaker will operate. A short time delay is applied to the incomer breaker to receive a block signal from the feeder relay. For non-directional relay greater than 40 ms setting is found satisfactory and more than 60 ms for the directional relay. This delay takes into account CT saturation[8].

For sectionalized busbars, 2 settings square measure to be incorporated wherever the best setting can trip the section or mechanical device breaker and once a time delay, if the fault current still persists, the sections will monitor individually and isolate the faulty part. The scheme got an inherent advantage that whenever there is the failure of the relay of the outgoing feeder; the busbar scheme will operate within a short period of time instead of the delayed operation of incomer backup overcurrent protection. The correct method of setting the CT ratios for the busbar differential protection is rather important[2]. It can be seen that the CT ratios of all the CTs are equal and are based on the primary current of that feeder which carries the maximum current, so that there will be no spill current through the OC relay connected within the spill path and also the theme remains stable[7].

3. WAVELET PACKET TRANSFORM

The wavelet packet method is a generalization of wavelet decomposition that offers a richer signal analysis[1]. Wavelet packet atoms are waveforms indexed by three naturally interpreted parameters: position, scale (as in wavelet decomposition), and frequency. For a given orthogonal wavelet function, a library of bases called wavelet packet bases can be generated. Each of these bases offers a particular way of coding signals, preserving global energy, and reconstructing exact features. The wavelet packets can be used for numerous expansions of a given signal[15]. We then select the most suitable decomposition of a given signal with respect to an entropy-based criterion. There exist simple and efficient algorithms for both wavelet packet decomposition and optimal decomposition selection. We can then produce adaptive filtering algorithms with direct applications in optimal signal coding and data compression.

In the orthogonal wavelet decomposition method, the generic step splits the approximation coefficients. A vector of approximation coefficients and a vector of detail coefficients, both at a coarser scale. The information lost between two successive approximations is captured in the detail coefficients. Then the next step consists of splitting the new approximation coefficient vector[17]; successive details are never reanalyzed. In the corresponding wavelet packet situation, each detail coefficient vector is also decomposed into two parts using the same approach as in approximation vector splitting. This offers the richest analysis: the complete binary tree is produced as shown in the following figure.

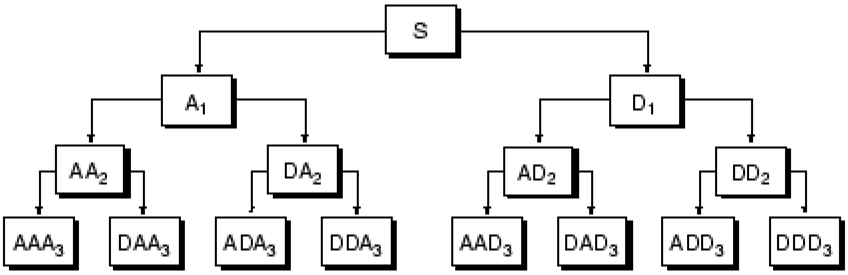


Fig 1. Wavelet packet Decomposition Tree at Level 3

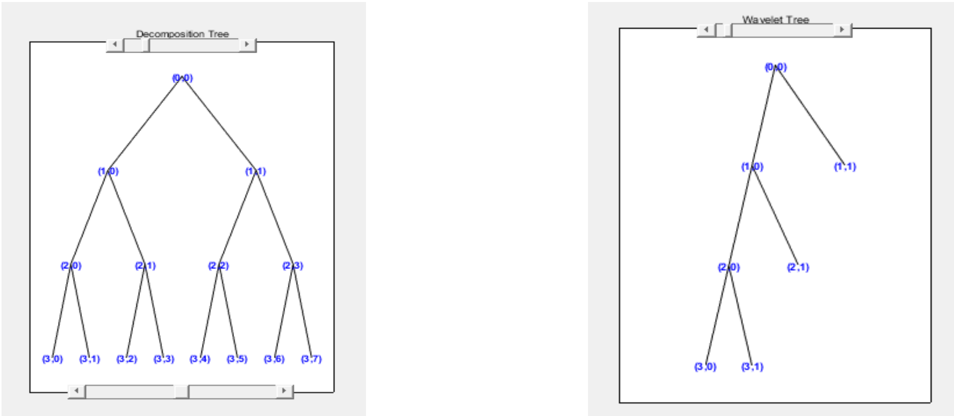


Fig 2. (a) Decomposition tree & (b) Wavelet tree

4. RESULTS AND DISCUSSION

To validate the proposal, IEEE 9 bus system is taken as test system. The system consists of three loads, six transmission lines (100km), three generators and three transformers. Fig 3 shows the one line diagram of IEEE 9 Bus system.

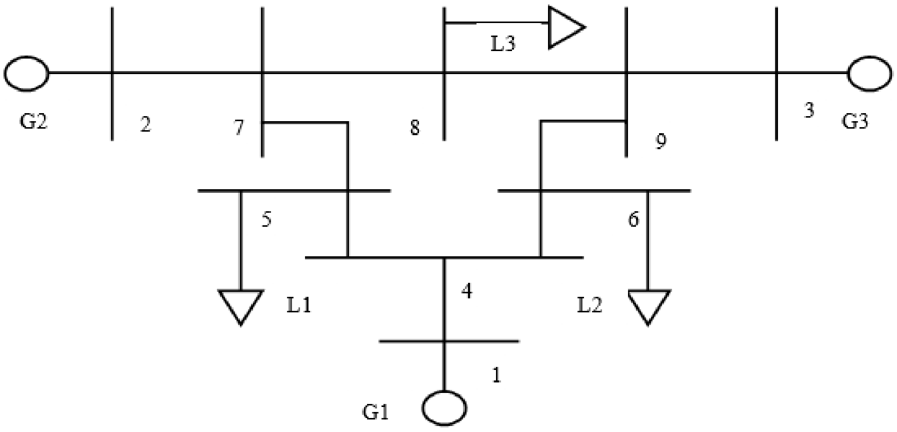


Fig 3. Single Line Diagram of IEEE 9 Bus System

Table 1. IEEE 9 Bus system Details

Generator 1	16.5kV	**Load 1**	230kV	**Transformer 1**	16.5/230kV
Generator 2	18kV	**Load 2**	230kV	**Transformer 2**	18/230kV
Generator 3	13.8kV	**Load 3**	230kV	**Transformer 3**	13.8/230kV

4.1 NORMAL CONDITION

In three phase differential relay for normal operation, the net incoming current value and outgoing current are same in each phase, so relay remains stable position.

4.2 INTERNAL FAULT

The fault that occurs nearest to the busbar 8 shown in fig 4 denotes as internal fault. In this case relay which senses and operates as the difference between the current entering into the busbar and the current leaving the busbar exceeds the set value.

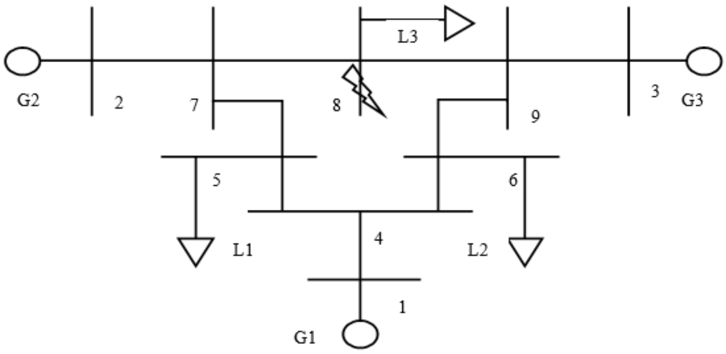


Fig 4. Internal Fault at Bus 8

CASE 1: SYMMETRICAL FAULT

All the phases are short circuited to each other and often to earth. Such fault is balanced in the sense that the systems remain symmetrical or the lines displaced by an equal angle 120°in three phase line. It is most severe type of fault involving largest current, but it occurs rarely. For this reason balanced short-circuit calculation is performed to determine these large current.

I. LLLG FAULT

In this IEEE 9 bus system, LLLG fault occurred in Bus 8 that is near to Load 3. When comparing incoming and outgoing current of Bus 8 is different, relay will tripped automatically as per setting time of relay.

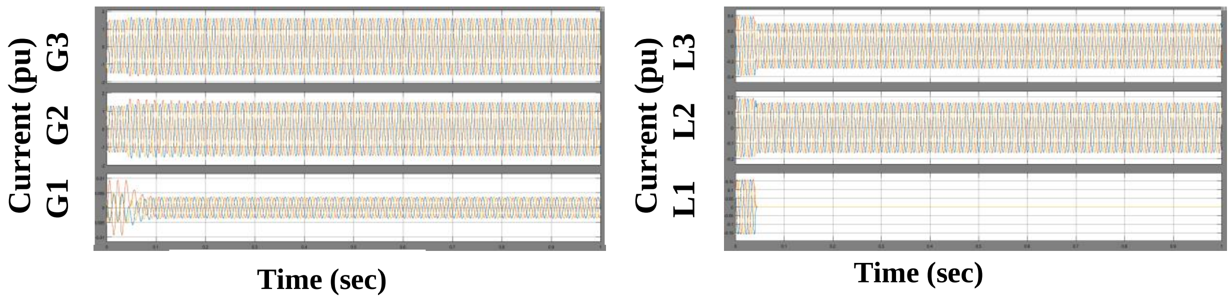
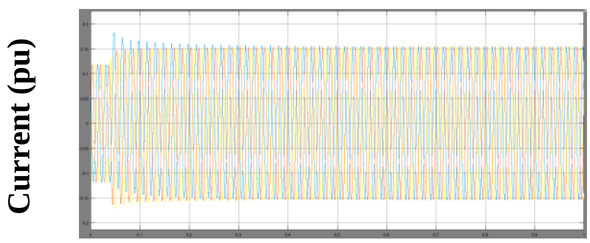


Fig 5. LLLG Fault at (a) Generator current & (b) Load current



Time (sec)

Fig 6. LLLG Fault at Plot current of Bus 8

The current of LLLG fault from workspace is export to wavelet transform to analyze the signal using decomposition tree method and mother wavelet of Daubechies family is computed. Db4 is one of the best to analyze of fault in power system. In this study Db4 at level is used to analyze the fault signal of LLLG of Bus 8.

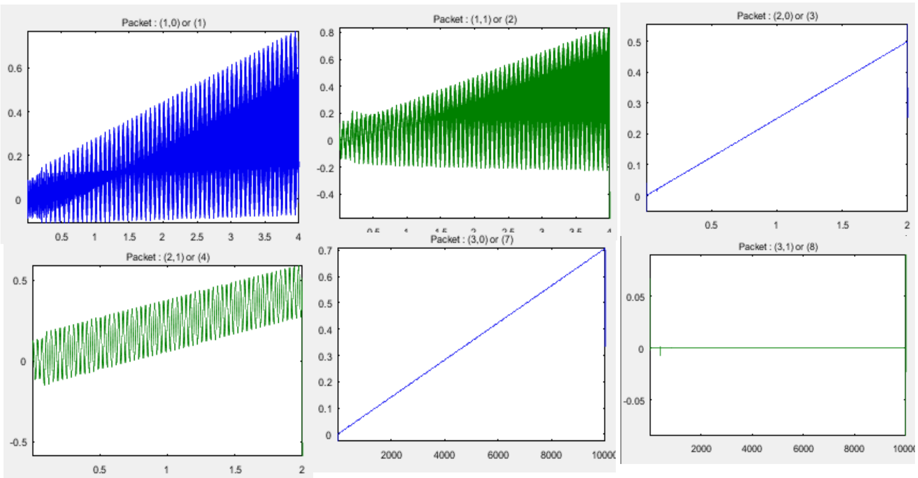


Fig7. LLLG Fault at Bus 8 Wavelet Transform Packet

The decomposition signal of fault signal is filtered to separate original signal and De-Noised signal. The de-noised signal is denotes as fault level of LLLG Bus 8. De-noised signal of LLLG fault is gradually increased to 0.25A and suddenly drop when setting time is appeared.

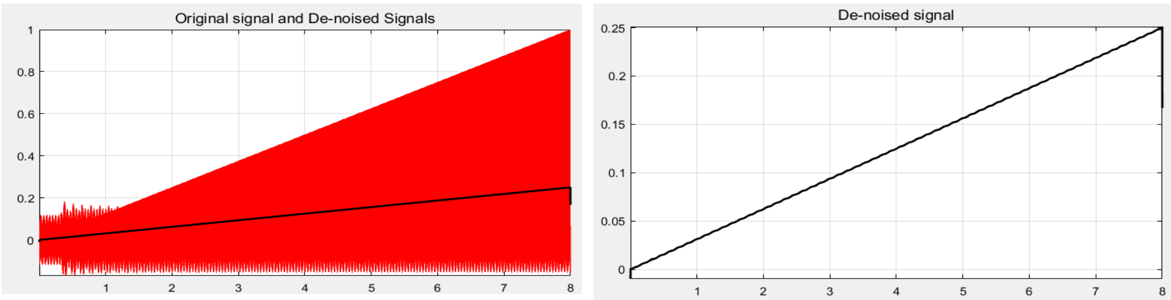
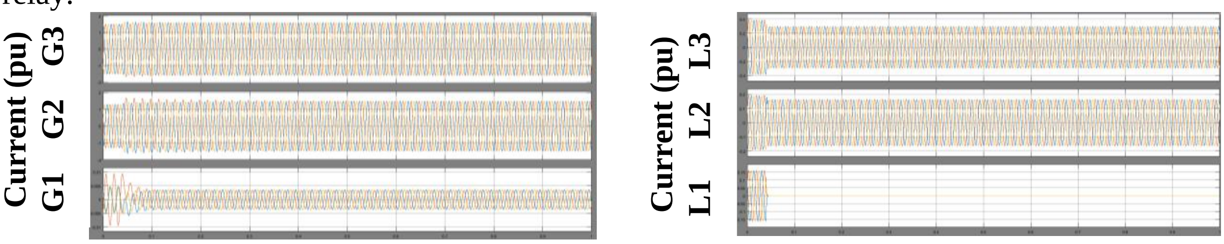


Fig 8. LLLG Fault at Bus 8 Original signal & De-noised Signal

II. LLL FAULT

In LLL fault of the power system all the phases are short circuited to each other. Such fault is balanced in the sense that the systems remain symmetrical, the lines displaced by an equal angle i.e. 120°in three phase line. It is most severe type of fault involving largest current, but it occurs rarely. For this reason balanced short-circuit calculation is performed to determine these large current. LLL fault is created in Bus 8 of Load 3 for analysis by comparing incoming and outgoing current of Bus 8, relay will tripped automatically as per setting time of relay.



Time (sec) Time (sec)

Fig 9. LLL Fault at (a) Generators current & (b) Loads current

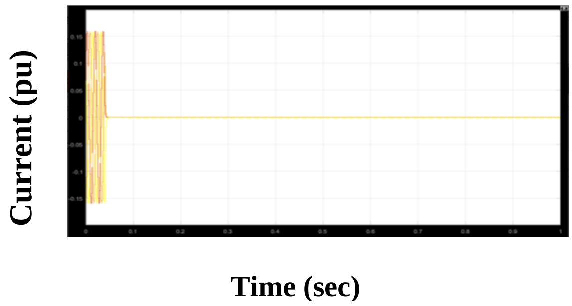


Fig 10. LLL Fault of Plot current at Bus 8

Similar analysis has been made as explained for LLL fault and status of relay has been verified. The decomposition signal of fault signal is filtered to separate original signal and De-Noised signal. The de-noised signal is denotes as fault level of LLL Bus 8. De-noised signal of LLL fault is gradually increased to 0.25A and suddenly drop when setting time is appeared.

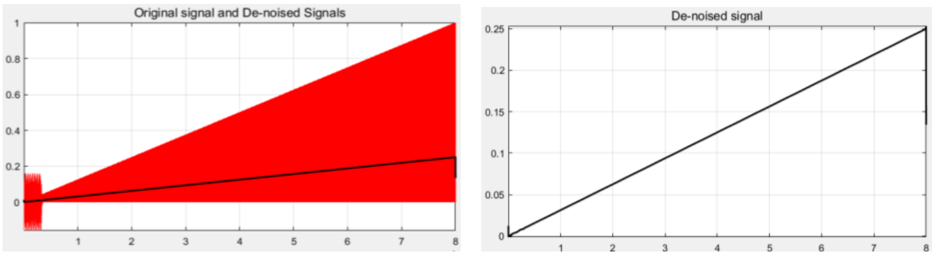


Fig 11. LLL Fault at Bus 8 Original signal & De-noised Signal

CASE 2: UNSYMMETRICAL FAULT

Unsymmetrical faults involve only one or two phases. In unsymmetrical faults the three phase lines become unbalanced. Such types of faults occur between line to ground or between lines. The effectiveness of the proposal is tested for unsymmetrical faults.

I. LG FAULT

Line to ground fault on a transmission line occurs when one conductor drops to the ground or comes in contact with the neutral conductor. In this IEEE9 bus system LG fault is occurred in Bus 8 of Load 3. By comparing incoming and outgoing current of Bus 8, relay will tripped automatically as per setting time of relay. The generator and load currents for the LG fault are shown in fig 12 (a) & (b).

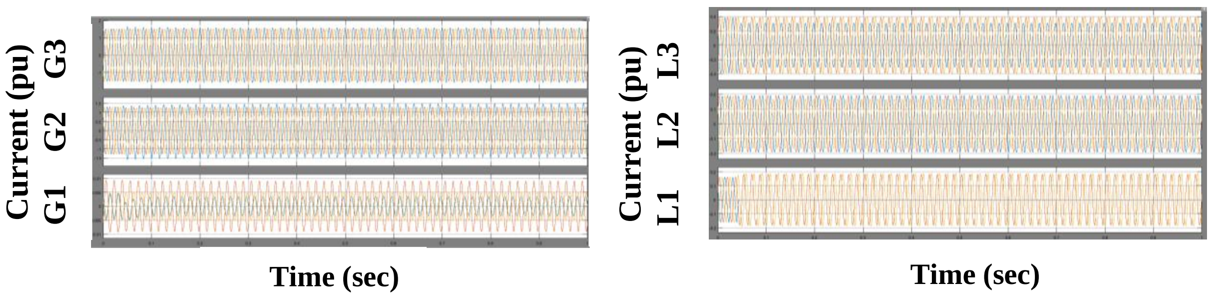


Fig 12. LG Fault at (a) Generator current & (b) Load current

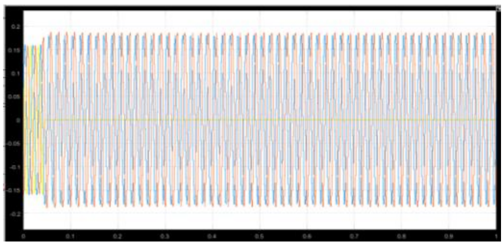


Fig 13. LG Fault of Plot current at Bus 8

The decomposition signal of fault signal is filtered to separate original signal and De-Noised signal. The de-noised signal is denotes as fault level of LG Bus 8. It is observed that the de-noised signal for LG fault is gradually increased to 0.3A and the signal is oscillated. In this type of fault it is found that the fault phase current is at negative position.

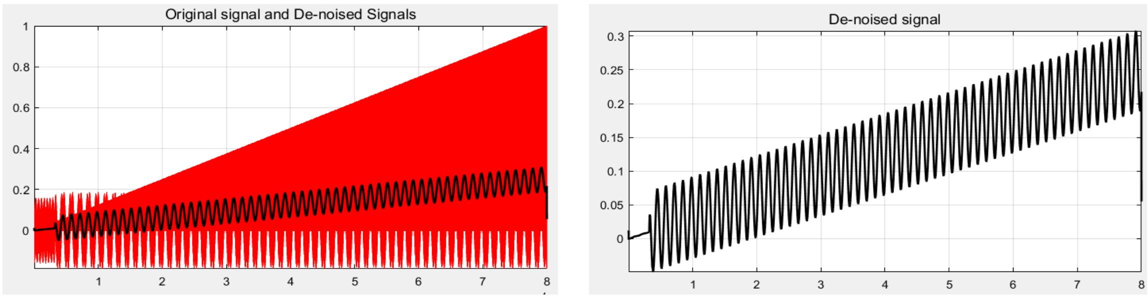


Fig 14. LG Fault at Bus 8 Original signal & De-noised Signal

II. LL FAULT

A line to line fault or unsymmetrical fault occurs when two conductors are short circuited. In a three phase system two different phases are short circuited it known as Line to Line fault. In that IEEE 9 bus test system LL short circuit has been made in Bus 8 of Load 3. Due to internal fault instantaneous overcurrent relay tripped automatically as per setting time of relay. The generators and loads current under LG fault in IEEE 9 bus system are shown in a fig 15 (a) & (b).

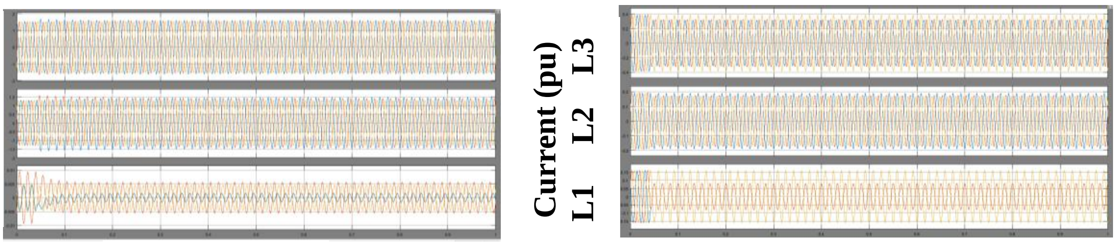
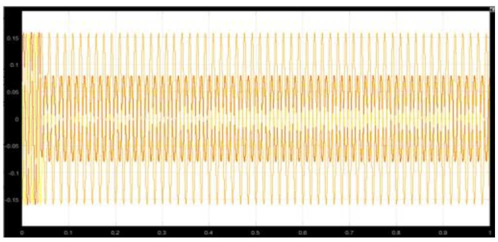


Fig 15. LL Fault at (a) Generators current & (b) Loads current



Time (sec)

Fig 16. LL Fault of Plot current at Bus 8

In LL fault any two are short circuited to each other. De-noised signal of LL fault is gradually increased to 0.25A and suddenly drop when setting time is appeared. In this type of fault it is observed that the two different phase current are drop to negative.

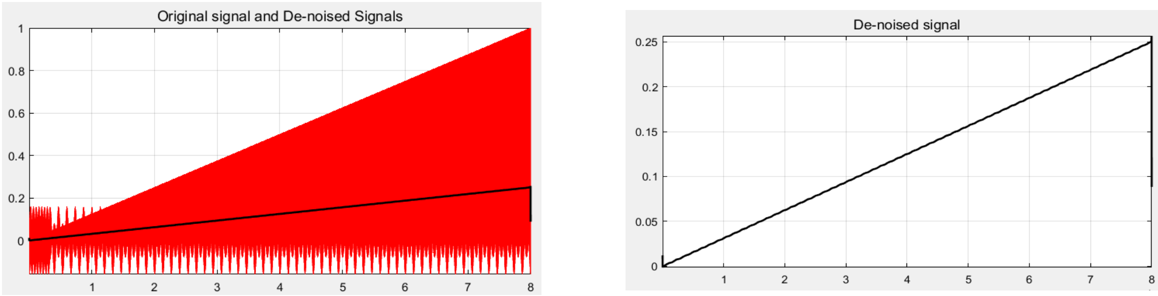
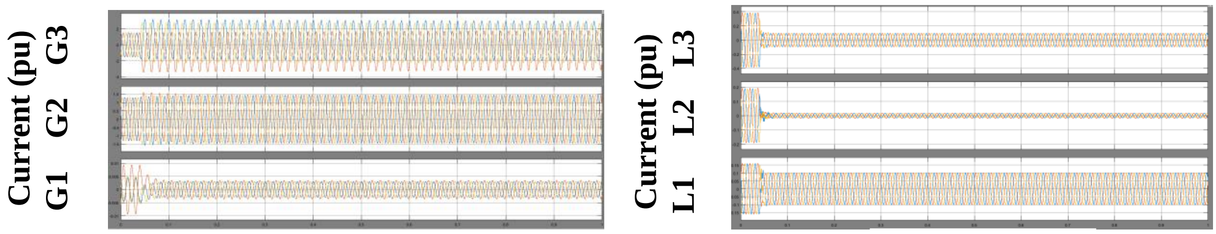


Fig 17. LL Fault at Bus 8 Original signal & De-noised Signal

CASE 3: FAULT AT VARIOUS LOCATIONS

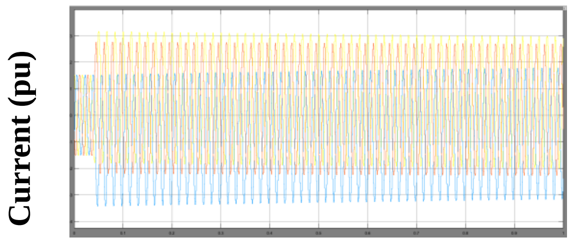
I. GENERATOR BUS

In this IEEE 9 bus system fault is occurred in Generator 1 at Bus 1. When comparing incoming and outgoing current of Bus 1 is different, relay will tripped automatically as per setting time of relay. In this type of fault Generator 1 current is drop down are shown in fig 18a. Imbalanced loads current occurred in this system are shown in fig 18b.



Time (sec) **Time (sec)**

Fig 18. Internal fault at Bus 1 (a) Generators current & (b) Loads current



Time (sec)

Fig 19. Internal fault of Plot current at Bus 1

Internal fault of Bus 1 is plot from workspace is export to wavelet transform to analyze the signal as decomposition tree method. In this decomposition method mother wavelet of Daubechies family is computed. Db4 is one of the best analyze of fault in power system. In this method Db4 at level is used to analyze the fault signal of internal fault Bus 1. The decomposition signal of fault signal is filtered to separate original signal and De-Noised signal. The de-noised signal is denotes as fault level of LLLG Bus 1. De-noised signal of LLLG fault is gradually increased to 0.25A and suddenly drop when setting time is appeared.

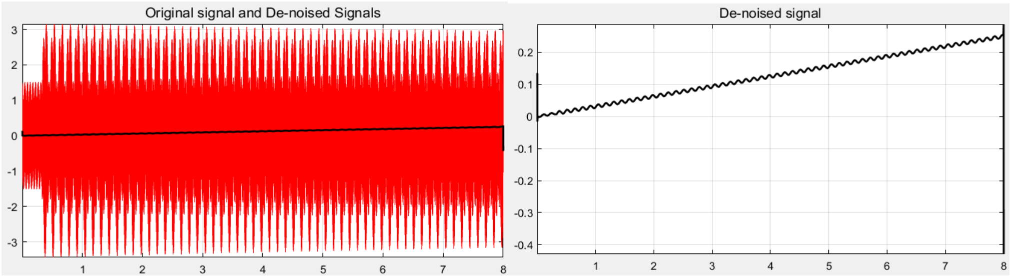


Fig 20. Internal fault of Bus 1 Original signal & De-noised Signal

II. LINE BUS

In this IEEE 9 bus system fault is occurred in line of Bus 4. LLLG fault is occurred very close to bus 4 it is denoted as internal fault and instantaneous overcurrent relay tripped automatically as per setting time of relay. Generator 1 current is pass through Bus 4, when fault is occurred in this bus current drop down. Generators current and loads current are shown in fig 21a & 21b.

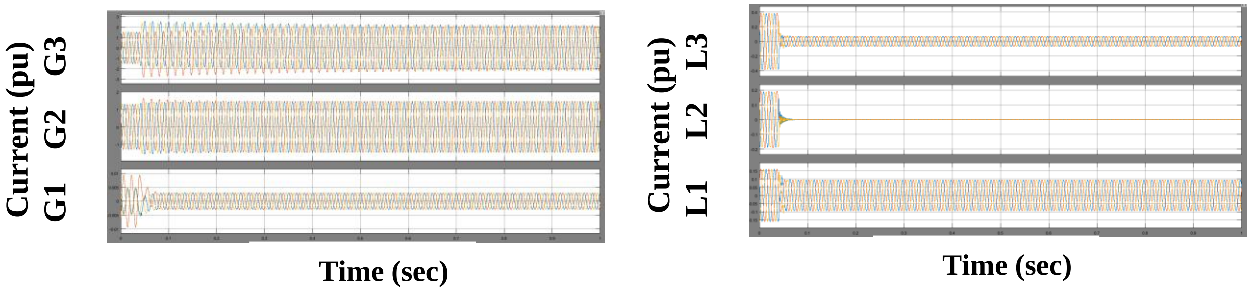


Fig 21. Internal fault at Bus 4 (a) Generators current & (b) Loads current

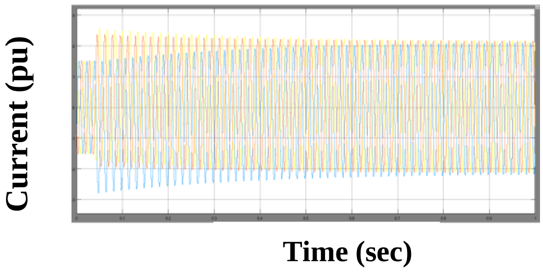


Fig 22. Internal fault of Plot current at Bus 4

Internal fault of Bus 4 is plot from workspace is export to wavelet transform to analyze the signal as decomposition tree method. In this decomposition method mother wavelet of Daubechies family is computed. Db4 is one of the best analyze of fault in power system. In this method Db4 at level is used to analyze the fault signal of Bus 4.The decomposition signal of fault signal is filtered to separate original signal and De-Noised signal. The de-noised signal is denotes as fault level of LLLG Bus 4. De-noised signal of LLLG fault is gradually increased to 0.25A and suddenly drop when setting time is appeared.

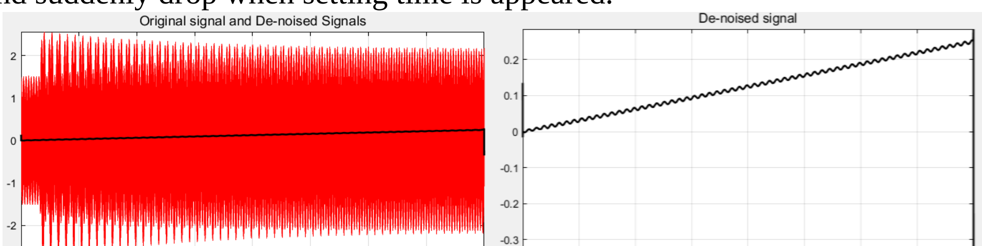


Fig 23. Internal fault of Bus 4 Original signal & De-noised Signal

4.3 EXTERNAL FAULT

To check effectiveness of the proposal with external fault, a fault has been applied is away from busbar 8. Now comparing incoming and outgoing current value of Bus 8 is same. Relay will not tripped, status of relay at Bus 8 is shown in fig 24. Also the generators current and loads current at Bus 8 were measured and presented in fig 25 a &b.

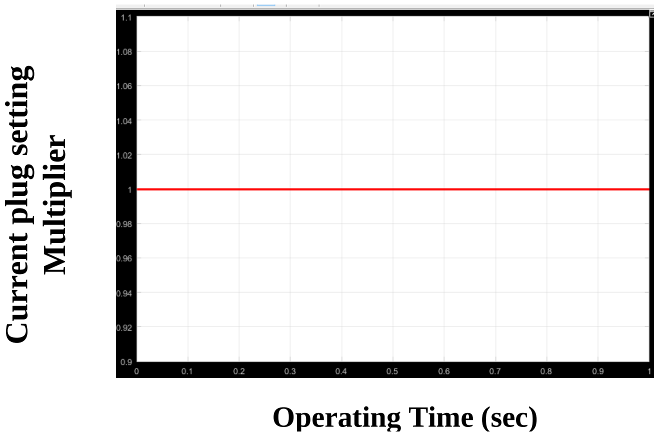


Fig 24. Status of relay at bus 8

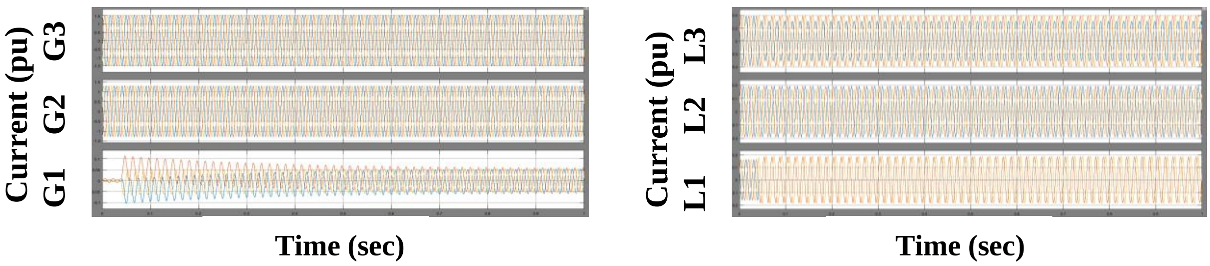


Fig 25. External fault of Bus 8 (a) Generators current & (b) Loads current

4.4 RELAY STATUS

Table 2. Relay Tripping Status

Types of fault			**Bus name**	**Relay status**	**Tripping time (sec)**
Internal fault	Symmetrical fault	LLLG	BUS 8	ON	0.02
		LLL	BUS 8	ON	0.02
	Unsymmetrical fault	LG	BUS 8	ON	0.02
		LL	BUS 8	ON	0.02
	Generator Bus	LLLG	BUS 1	ON	0.05
	Line Bus	LLLG	BUS 4	ON	0.02
External Fault			BUS 8	OFF	-

5. CONCLUSION

In this work, an algorithm has been developed to improve the selectivity of the relay and the same has been tested for a short circuit in IEEE9 bus system for internal and external faults. Separation of De-noised signal from fault signal is made using wavelet transform so that the nature of fault occurs on the system can be identified. In this study Daubechies 4 at level 3 is used to separate original signal and de-noised signal. The entire simulation has been done using MATLAB R2017a and the simulation results validate the proposal.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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