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DISCRIMINATION TECHNIQUE FOR INTERNAL FAULT AND INRUSH CURRENT OF POWER TRANSFORMER BY USING WAVELET DETAIL COEFFICIENTS OF CURRENT SIGNAL

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ABSTRACT

In the transformer protection, the critical importance is to distinguish the current response due to the internal fault and the inrush condition. If they are not definitely discriminated, some of the transformer protected relay especially the differential relay may cause sending of faulty signal to the circuit breaker. The discrimination technique is based on the Discrete Wavelet Transform using the method of different behaviour of current waveform under internal fault and inrush condition. For such discrimination, an algorithm is presented which can be applied under various transformer operating conditions. For detail study, 66/11-kV, 20MVA Δ/Yn transformer from Pyay Substation, Myanmar is selected. The simulation of inrush current due to energization and internal fault currents are performed using Sim power system. From the simulation result, transformer input currents are observed and recorded. At that point, the current sign is decayed and removed by utilizing Discrete Wavelet Change. Arrangement of inrush and the inside issue is acquired by utilizing the extents of two continuous purposes of An and B. The outcome shows that the proposed strategy can be precisely used to recognize the interior deficiency and inrush current of the force transformer.

Keywords: *Discrimination Technique, Transformer internal fault, Inrush current, Discrete Wavelet Transform(DWT), Detail Coefficients db5, Current Waveform behaviour.*

I. INTRODUCTION

When the internal fault occurred in the power transformer, the excess of the currents flow in the windings but the wave shapes are different from that of the inrush current The magnetizing inrush current occurs at the time of energizing the transformer which the current may be up to ten times higher than the normal rated current of the transformer and therefore can cause the mal-operation of the differential relay [1]. To overcome this mal-operation of the differential relay, many methods have been presented to analyze and recognize the inrush and internal fault current [2]. Among them, the wavelet transform is selected for analyzing power transformer transient. Because it is a good ability to extract information from the transient signal in terms of both time and frequency domain [3].

Wavelet-transform based signal processing technique is an effective tool for power systems analysis and feature extraction [4]. Discrete Wavelet Transform is applied to decompose the current signal of internal fault and the inrush current of the power transformer into detailed coefficients in a specific frequency band [5].

To literature [1], the diagnosis process of DWT is based on the different characteristics of current waveforms. By quantifying the extracted features is defined in terms of time difference of the magnitudes of wavelet coefficients over a specific frequency band.

This paper presents a method to discriminate between the internal fault and the inrush current of the power transformer using Discrete Wavelet Transform (DWT). Firstly, the phase current signal from the simulation result is decomposed. Secondly, the distinctive signal features in detail 5 of internal fault and inrush current are extracted. After quantifying the extracted features, take different two peak magnitudes from detail 5. By comparing these magnitudes of the phase current signal, the internal fault can be accurately discriminated from inrush current.

The paper is organized as follows: the proposed methodology based on discrete wavelet transform is detailed in section II. The case study area is described in section III. Then, the simulation results of MATLAB/SIMULINK and DWT are presented in section IV. The conclusion is drawn in the final section.

II. METHOD FOR DISCRIMINATION TECHNIQUE

(a) Application of Discrete Wavelet Transform

The wavelet analysis and wavelet transform have developed as a powerful tool for signal processing in different applications. The transient characteristics of wavelets can be used to extract and analysis of signals on the complex frequency-time planes [6]. There are many applications of wavelet transform in power systems such as analysis and detection of electromagnetic transients, power quality assessment, data compression, and fault detection [7]. The implementation procedure of a Discrete Wavelet Transform [8], in which S is the original signal, Low Pass Filter (LPF), High Pass Filter (HPF) is respectively shown in figure (1).

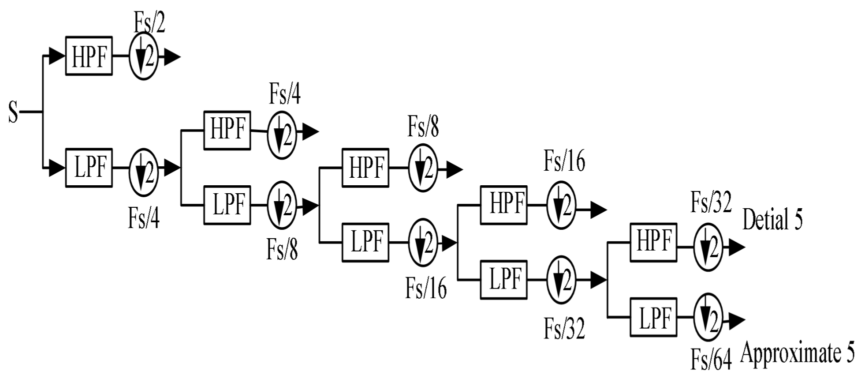

Figure (1). Implementation of Discrete Wavelet Transform

Initially, a unique sign is isolated into equal parts of the recurrence transfer speed. It was shipped off both HPF and LPF. Furthermore, the yield of LPF is sliced down the middle of the recurrence transmission capacity which is known as the second stage. This measure does again until the sign is deteriorated to a pre-characterized certain level. If the first sign was being characterized as testing recurrence (Fs, Hz) at that point the most noteworthy recurrence was Fs/2 Hz in detail 1. The frequencies between Fs/2 and Fs/4 would be caught in detail 2, etc [9]. In this work, the inspecting recurrence is set to be at 20 kHz. The recurrence levels of the wavelet coefficients are appeared in table (1).

Table (1). Frequency Levels of Wavelet Function Coefficients

Sr No.	Decomposition Level	Frequency Component,	Unit
1.	D1	10000-5000	Hz
2.	D2	5000-2500	Hz
3.	D3	2500-1250	Hz
4.	D4	1250-625	Hz
5.	D5	625-312.5	Hz
6.	A5	0-312.5	Hz

(b) Different behaviour of inrush current and internal fault

The polarizing inrush current identifies with the transformer center immersion has a conelike shape. All in all, the inrush current at the exchanging time at first increases very gradually, and over the long haul its slant increments. At the point when a deficiency happens, the differential current has a higher incline contrasted

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and the beginning of the inrush current, and its slant diminishes over the long haul. Figure (2) outlines the diverse conduct of inrush current and inside flaw.

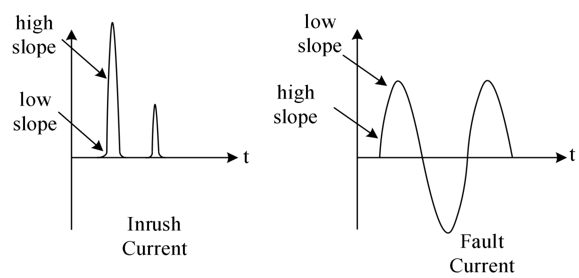

Figure (2). Different behaviour of inrush current and internal fault

Since these highlights come from the diverse idea of the flows and boundaries of the transformer and the associated power framework doesn't impact it. Consequently, these highlights of distinction between the underlying slants of the differential current waveform might be utilized as the premise of separating the shortcoming from the inrush current [10].

(c) Proposed Algorithm

The proposed algorithm of discrimination between internal fault and inrush current is shown in figure (3).

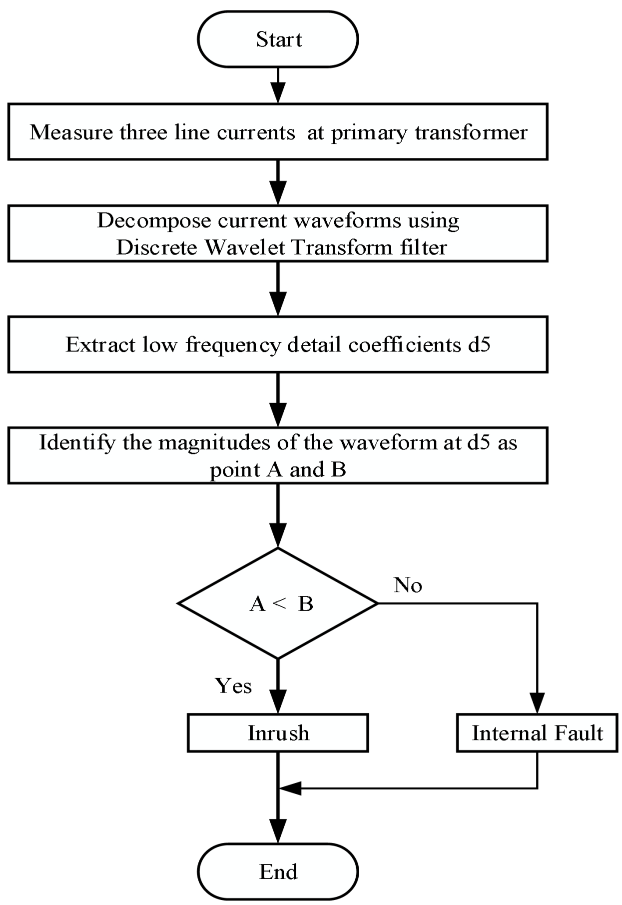

Figure (3). Flowchart of Proposed Algorithm

Step-by-step procedures of decomposition and extraction of the signal are described as the following:

- Measure the current at the primary side of the simulation result.
- Import current signals to Discrete Wavelet Transform
- Decompose the current signals by using Daubechies (db5) wavelet
- Extract the signals from the low-frequency detail 5 coefficients
- Identify the magnitudes on the waveform from the d5. The two consecutive points of the waveform are referred to as "A" and "B".
- Compare the two consecutive points of the waveform

II. CASE STUDY

To show the effectiveness of the proposed method, the required signals such as phase current should be attained through simulation of different conditions such as a transformer connected with loaded and unloaded conditions.

Therefore, a suitable power system is modeled with a source, circuit breaker, a power transformer, and load by using Simpowersystems [11]. Modeling of the power system under study can be subjected to different conditions such as switching and internal fault. The 66/33/11kV, 100MVA Pyay sub-station is used as a studying area. This substation has three transformers with their respective rating. Among them, 66/11kV, 20MVA power transformer is used for different conditions. The data for the power system of case study is shown in the table (2).

Table (2). Data for the Power System of Case Study

Sr No.	Types	Parameters	Values	Units
1.	Source	Capacity	100	MVA
		Voltage	66	kV
		Frequency	50	Hz
2.	Transformer	Capacity	20	MVA
		Voltage	66/11	kV
		Winding Resistance	0.002	p.u
		Winding Inductance	0.08	p.u
		Magnetization Resistance	500	p.u
3.	Load	voltage	11	kV
		Active Power	10.4	MW
		Reactive Power	8.7	MVar

III. RESULT AND DISCUSSION

In this section, simulation models for inrush current conditions and transformer internal fault conditions are presented. From the simulation results, the current signals under different abnormal conditions are recorded. A total of 26 sets of the signals were captured for inrush and internal fault at different conditions. This captured data are then analyzed for inrush and internal fault by using discrete wavelet transform.

(a) *Simulink Model*

The simulation model of the power transformer during energization is shown in figure (4). Inrush current is caused during energization. To attain the sampling frequency of 20kHz, the sampling time is set at 50μsec in the "powergui" block. Simulation time sets 0.5sec. In this model, the switching state is set at 0.2s in the breaker. The transformer model parameter is chosen as the saturation state. Thus, this is a complete model for energization.

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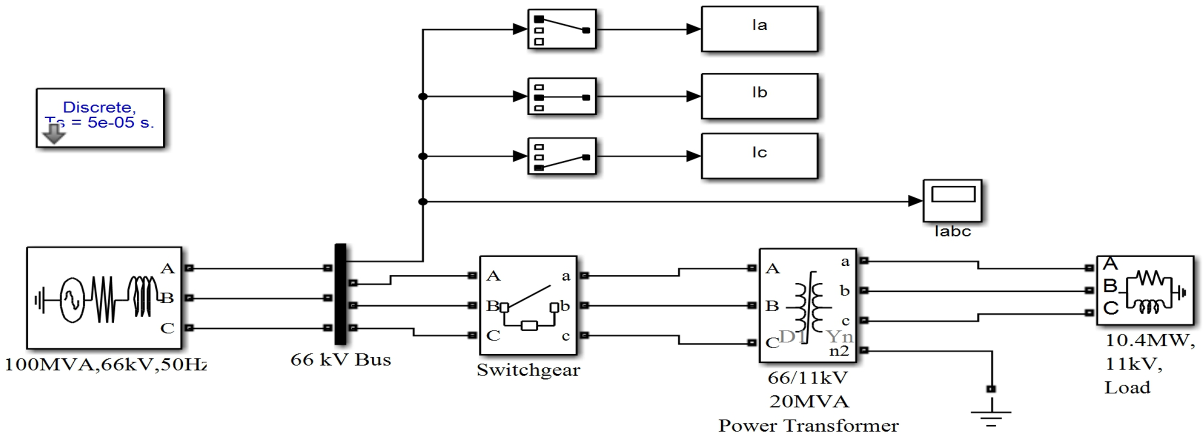

Figure (4). Simulation the model of Power Transformer during Energization

The simulation model of the power transformer during the internal faults such as the phase to earth fault and the phase-to-phase fault are created by using a fault block as shown in figure (5). Switching time is created the various fault conditions between 0.2s to 0.5s.

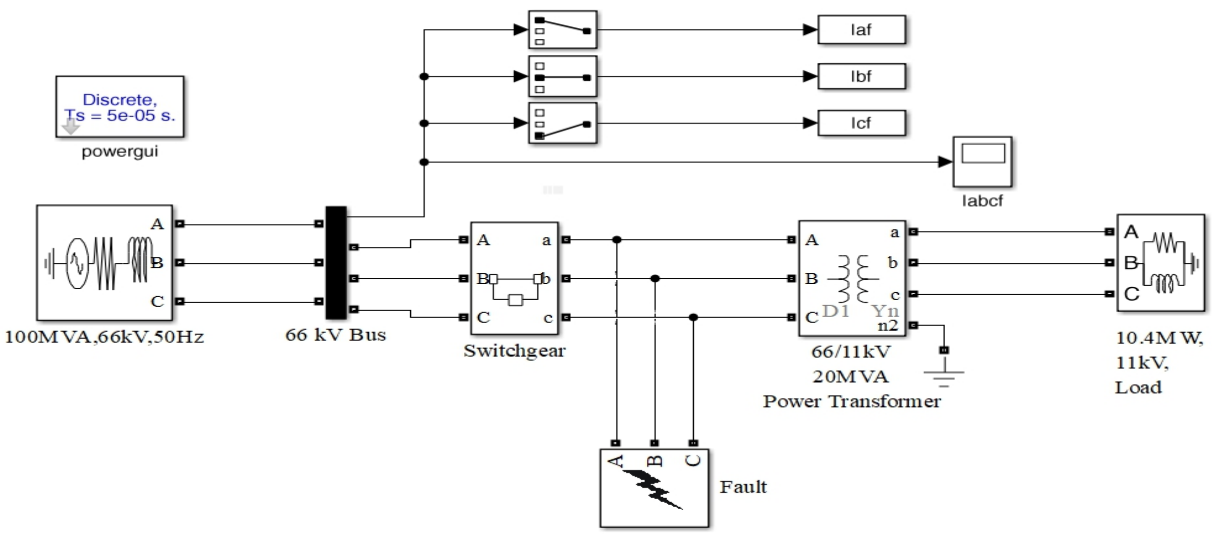

Figure (5). Simulation Model of Power Transformer during internal Fault

(b) *Simulation Results for Inrush and Internal Fault Current*

In this section, the performance of power transformer under different conditions and the wavelet transform application will be studied. It has also considered the various types of internal faults that occurred in three-phases and analysis has been done for all the types of internal faults.

Figure (6), (7) and (8) shows the waveforms of all the three-phase currents under energization and internal fault conditions with the loaded and unloaded conditions. The horizontal axis shows the time duration and the vertical axis gives the magnitude of the current under various conditions of the system.

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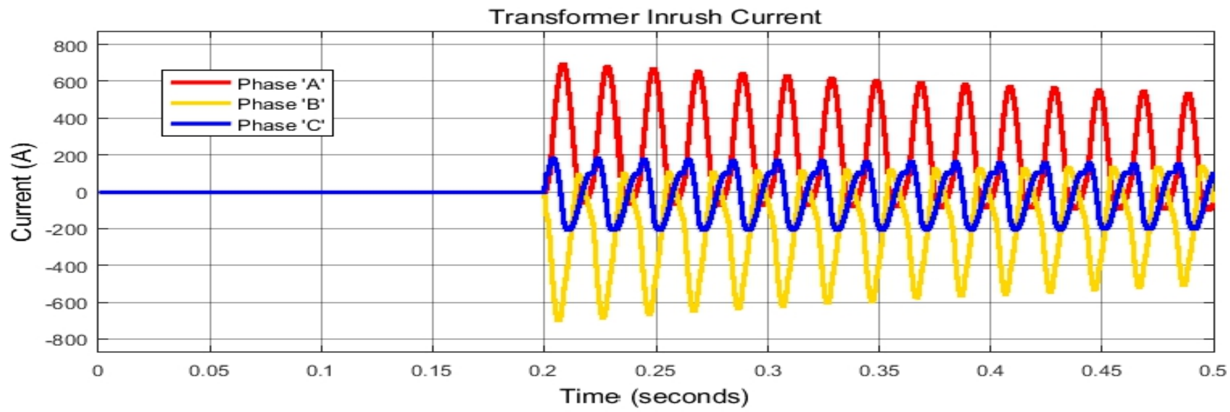

Figure (6). Simulation Result of Inrush Current during Energization

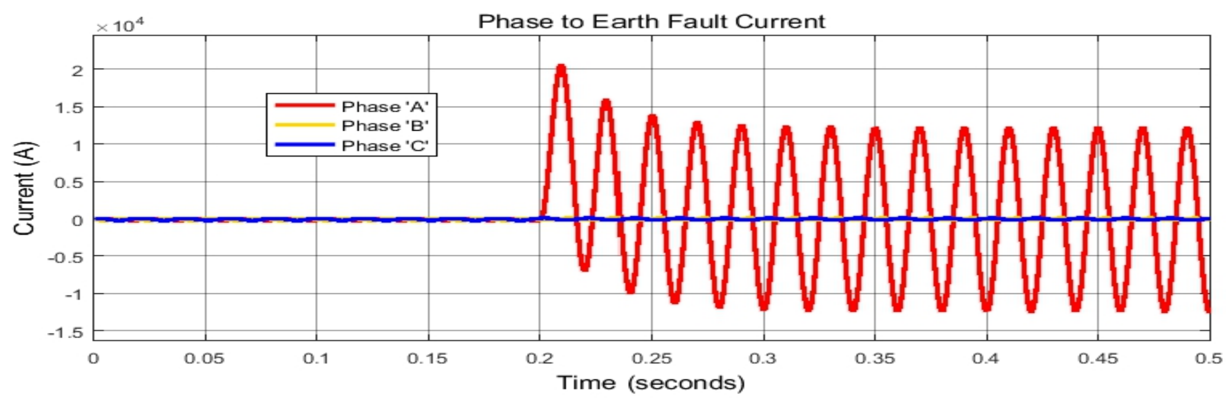

Figure (7). Simulation Result of Phase to Earth Fault Current at Loaded Condition

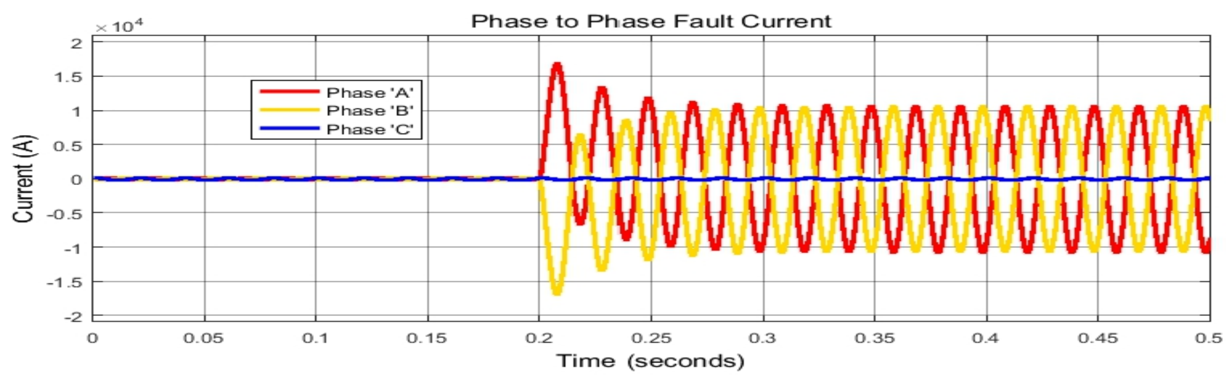

Figure (8). Simulation Result of Phase to Phase Fault Current at Loaded Condition

Table (3). Simulation Results of current for Various Types of Two Conditions

Sr No.	Condition	Type	Phases	RMS Value of Current, A
1.	Loaded	Inrush	A	259.2 A
			B	244.3 A
			C	101.1 A
		Phase to Earth	AG	6987 A
			BG	6809 A

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			CG	6749 A
		Phase to Phase	AB	6047 A
			BC	5838 A
			CA	5946 A
2.	Unloaded	Inrush	A	113.6 A
			B	97.95 A
			C	32.05 A
		Phase to Earth	AG	6991 A
			BG	6807 A
			CG	6751 A
		Phase to Phase	AB	6023 A
			BC	5925 A
			CA	5810 A

In Table 3, the simulation results of transformer currents to be distinguished under loaded and unloaded conditions are described. The RMS value of inrush current at loaded condition is significantly higher than comparing in unloaded condition. However, the RMS value of phase to earth fault and phase to phase fault current at loaded condition is slightly lower than comparing in unloaded condition.

(c) *Results from Decomposition of the Signals by Using Discrete Wavelet Transform*

To observe in the discrete wavelet transform, firstly the current through all the three phases are tapped to MATLAB workspace. The data of a current signal is decomposed to the detail and the approximation coefficient using a wavelet toolbox. The decomposition of the current signal is done by using Daubechies in the discrete wavelet transform with vanishing moments of five orders (db5) at level 5.

The five-level coefficient waveforms are got along with the signal, detail signal, and the approximation signal is shown in figure (9), (10) and (11) for various conditions. From figure (9), (10), (11), the inrush, the phase to earth, the phase to phase current signal is seen in d1to d5 from the waveform. But the low-frequency detail coefficient at level 5 is seen clearly and it is chosen to discriminate the signals for all conditions.

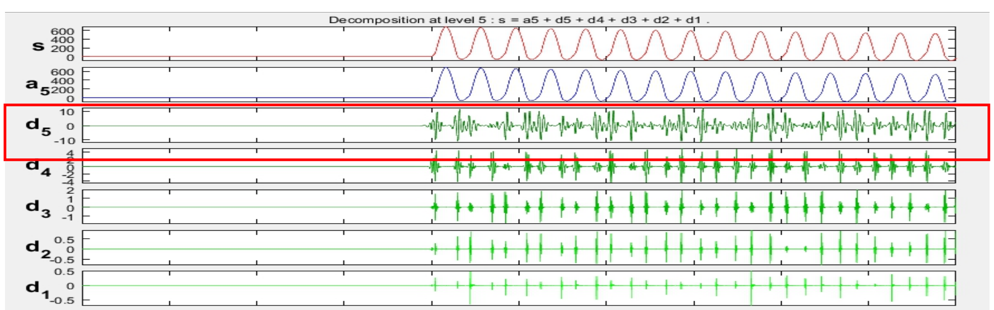

Figure (9). Five Level Wavelet Analysis of Inrush Current for Phase A at Loaded Condition

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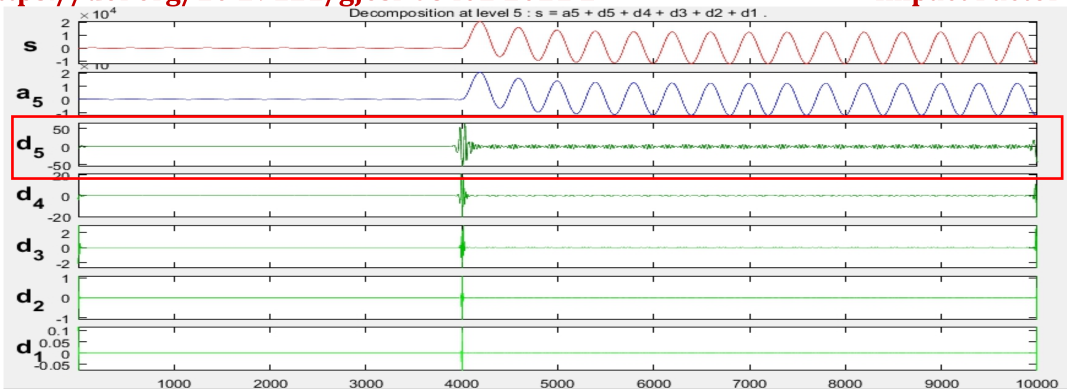

Figure (10). Five Level Wavelet Analysis of Phase to Earth Fault for Phase A at Loaded Condition

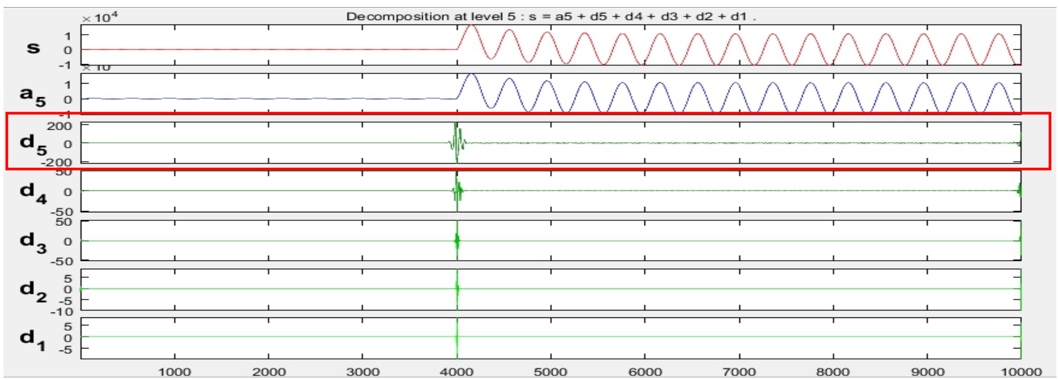

Figure (11). Five Level Wavelet Analysis of Phase to Phase Fault for Phase A at Loaded Condition

(d) *Results from Extraction of the Signals by Using Discrete Wavelet Transform*
To obtain the proposed method, the amplitude of detail coefficient at d5 is used. Figure (12), (13) and (14) shows that the amplitude of detail coefficient at d5 for inrush, phase to earth, and phase to phase fault of the current signal. In this figure, A and B are the magnitudes of the first two consecutive peaks of the disturbance waveforms.

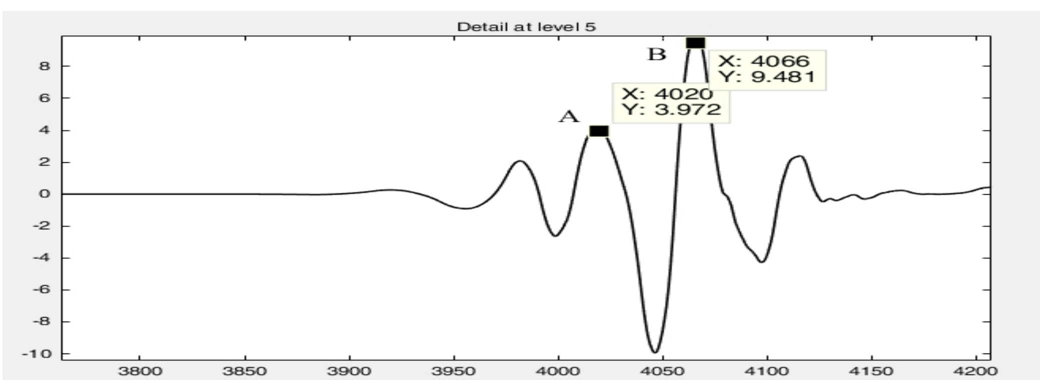

Figure (12). |d5| of Inrush Current for Phase A at Loaded Condition

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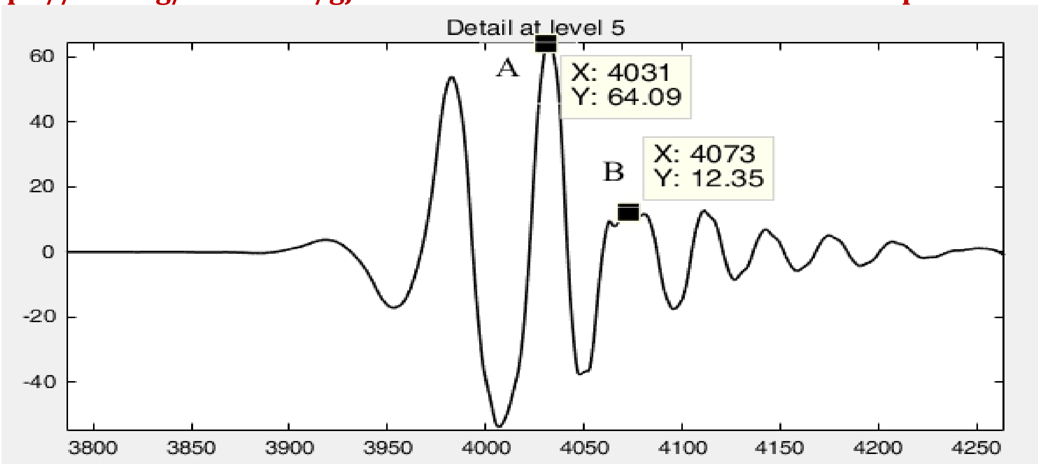

Figure (13). |d5| of Phase to Earth Fault for Phase A at Loaded Condition

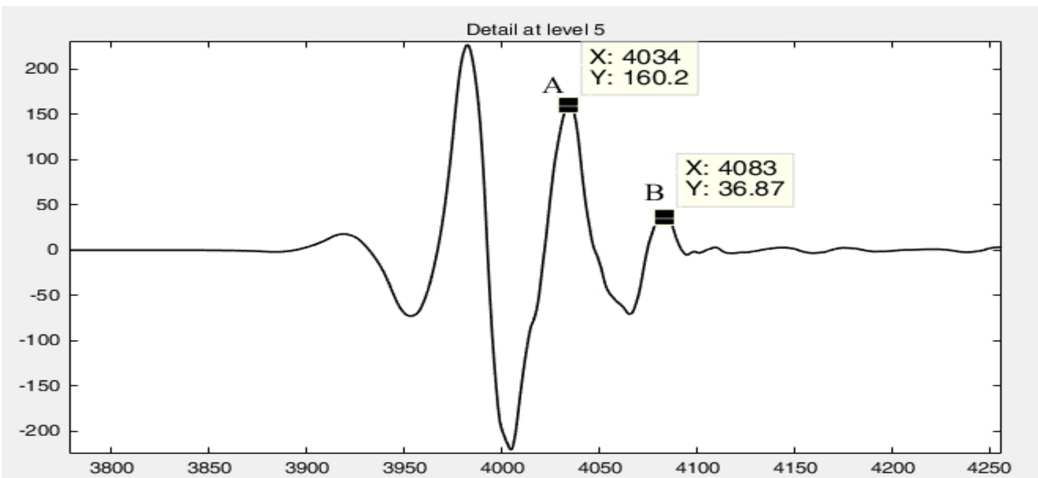

Figure (14). |d5| of Phase-to-Phase Fault for Phase A at Loaded Condition

When the magnitudes are compared on the current waveform, the inrush current exhibits a different behavior than the fault current. Inrush current starts with a low slope and increase. The two consecutive peak points A and B can be obtained and compared. It can be noted that A>B, there is an inrush. Then A<B, there is an internal fault. The absolute values and results of detail coefficients at d5 for inrush, phase to earth, and phase to phase fault of the current signals are shown in the table (4).

Table (4). Absolute Values and Comparison Results of Detail Coefficients at d5 for Inrush, Phase to Earth and Phase to Phase Fault Current Signals

Sr No.	Categories	Phases	Condition	A		B		Result	
								Inrush Current	Internal Fault
				X	Y	X	Y	A < B	A >B
1	Inrush Current	A	Loaded	4020	3.972	4066	9.481	✔	
2	Phase to Earth Fault	AG		4031	64.09	4073	12.35		✔
		BG		4064	145.8	4117	15.52		✔
		CG		4036	203.9	4085	61.5		✔
3	Phase to Phase Fault	AB		4034	160.2	4083	36.87		✔

		BC		4065	153.5	4115	21.78		✔
		CA		4038	77.67	4086	28.07		✔
4	Inrush Current	A	Unloaded	4047	8.045	4098	14.98	✔	
5	Phase to Earth Fault	AG		4031	64.53	4073	11.98		✔
		BG		4064	147.9	4117	15.85		✔
		CG		4036	204.5	4085	61.76		✔
6	Phase to Phase Fault	AB		4034	163.2	4083	38.49		✔
		BC		4065	155	4115	22.09		✔
		CA		4038	76.79	4086	27.9		✔

IV. CONCLUSION

In this paper, a novel technique for segregating the various flows of the force transformer is used. This proposed strategy depends on the diverse conduct of the stage current waveform. Daubechies wavelet with disappearing snapshots of five orders at level 5 in DWT is utilized for the deterioration of the sign. The sign extraction depends on assessing the DWT coefficients of the five-level details. For testing the proposed calculation, three cases with different conditions were utilized. The outcomes indicated that it is quick, exact, discriminative, and solid capacities of the DWT to recognize various qualities of flows streaming in a force transformer under different conditions.

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