Evaluation of Digital Wavelet Filter on Low Voltage Arcing Detection Equipment

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***Abstract*— Arcing is one of the causes of fire disasters that occur quite a lot in the world. The danger of arcing causes enormous losses. The fault current caused by arcing usually occurs in a very short duration, so that safety equipment such as Miniature Circuit Breaker (MCB) and Fuse cannot detect the disturbance. If arcing takes place continuously, there will be heat that can damage the equipment and cause a fire. In this study, an evaluation of the use of mother wavelets in the Discrete Wavelet Transform (DWT) method on low voltage detection equipment will be carried out. DWT is a mathematical function that is the most successful in the field of signal processing. Signal processing using the DWT method will be analyzed and compared its performance with mother wavelets Daubechies-1, Daubechies-4, Coiflet-4, and Symlet-4. Then applied to low voltage arcing detection equipment. From the results of testing and analysis obtained the mother wavelet Daubechies-4 produces a high level of accuracy and sensitivity. Mother wavelet Coiflet-4 and Symlet-4 produce the lowest level of accuracy at 400W and 700W load. Meanwhile, on the mother wavelet Daubechies-1, the normal signal amplitude value is close to the arcing signal amplitude value, so it will be difficult to determine the threshold value. In this study, the results obtained are arcing detection equipment using the mother wavelet Daubechies-4 method can detect arcing disturbances very well and produces a high level of accuracy and sensitivity compared to the mother wavelet Daubechies-1, Coiflet-4 , and Symlet-4.**

Keywords—arcing, discrete wavelet transform, low voltage, mother wavelet.

I. Introduction

Electricity has become a very important and primary need for every society in everyday life. Users of electrical energy in Indonesia are increasing every year, this causes every region in Indonesia to have an electrification ratio that continues to increase every year. According to the Directorate General of Electricity at the Ministry of Energy and Mineral Resources (ESDM), the electrification ratio as of May 2019 has reached 98.81 percent and the latest data as of May 2020 shows the ratio reached 98.93 percent. Furthermore, the Ministry of Energy and Mineral Resources targets an increase in electricity utilization per capita to 2500 kWh by 2025, with the electrification ratio at the end of 2020 reaching 99.99 percent [1]. The increase in electricity demand in Indonesia is also directly proportional to accidents caused by electricity in Indonesia which also increases every year. The fire disaster statistics site for DKI Jakarta Province states that until the end of 2019, there were 1355 fire cases with 577 cases caused by short circuits or electrical short circuits [2]. In a short-circuit fault, the current value is very large, if the short-circuit current value exceeds the resistance of the electrical current-conducting material, it will cause damage to the equipment and can cause a fire. However, if the conductors between the interconnected conductors have very thin filaments and touch each other, the MCB and fuse safety devices cannot detect it because the short-circuit current occurs very quickly and does not exceed the safety specifications. This disturbance is known as parallel arcing disorder. There are also cases of unavoidable interference, this disturbance is called series arcing. In this disturbance the safety is also unable to detect because the current does not exceed the specification capability of the safety. If series arcing occurs continuously, then the one-way conductor that should have no potential difference will appear a potential difference which will eventually release energy in the form of heat and eventually ignite. Arc interference is divided into 3 types: (i) Contact Arc. (ii) arc without contact by carbonized track; (iii) arc without contact by electric breakdown; Contact arc may occur with a partial break of the electrical wiring. An increase in current density will create occasional heating through the Joule effect. Such heating may cause the fusion of conductors, but it does not interfere with the conduction current. The arc without contact by electrical damage is regulated by Paschen's law, which determines the relationship of broken voltage, pressure and gap distance. Regarding LV electrical installations, this type of arc is unusual. It usually occurs due to an increase in voltage caused by atmospheric discharge. The arc without contact by carbonized track usually happens in installations that were poorly implemented or lack maintenance. They usually happen when the insulation layer of the cables is damaged. In this case, the arc by carbonized track may be generated by sparkles through moisture and contamination, which will generate small discharges due to damage in the electric insulation

The first type of detection method depends upon the temporal analysis of the electrical characteristics of the current. The various characteristics of arc waves can be used as evaluation materials to detect patterns in the presence of disturbance. The detection of the arc is not a trivial task, being related to the path of the arc fault current. Based on this criterion, the arc fault may be classified as serial arc fault and parallel arc fault

In 2017, Pratik kumas s has conducted research on Arc Fault Detection in Low Voltage DC System Using Wavelet

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Transform. In the paper, researchers use wavelet transform because this method is felt to be able to recognize complicated DC signal patterns because the DC system cannot be based on zero junction values depending on the Fourier transformation which is the recognition of signal patterns either in the time domain or the frequency domain which cannot provide accurate results. In 2021 wavelet-analysis-based singular – value – decomposition (WASVD) algorithm use to verify various experiments including single load and parallel load with different operations current amplitudes and arc generators mounted in series with each load generating series or parallel arc error. The results showed that the proposed algorithm, without manual retuning parameters, has achieved outstanding detection accuracy compared to traditional weak arc error detection methods.

In this study, the researchers used DWT as a method for detection experiments at low voltage levels. Because from existing experiments have never been the use of this method low voltage.

In this paper will be discussed into 5 sections. The first introduction contains about the background of the researcher and explains the previous research, and the research to be carried out. Section two contains the theoretical basis of the wavelet transform method and how it detects arcs. Chapter 3 will discuss the concept of outline research and the stages for conducting arc detection experiments at low voltage levels. Chapter 4 contains the results of experimentation and data analysis. Chapter 5 contains conclusions drawn from experiments already carried out.

II. ARC FAULT AND WAVELET TRANSFORM METHOD

A. *Arc Fault*

An arc fault is a spark in an electrical system that occurs when two single-phase and one-phase conductors with a neutral touch and there is a surge in current between the two conductors due to a sufficient voltage value. This spark then ionizes the surrounding air, so that the surrounding air becomes conductive and forms an arc of fire [3]. The arc also usually followed by the phenomenon of arc flash. According to NFPA [4], Arc flash is a phenomenon of the release of energy in the form of heat and light from the ionization process (electron multiplication) that occurs in the air from a material. The arc flash phenomenon plays an important role in the event of a fire. Conventional safety devices such as MCB (Miniature Circuit Breaker) and fuses cannot detect very high currents and trip as expected. This is because the duration of the short circuit is very fast so that it cannot be detected by conventional safety devices such as fuses or MCBs [5-7].

B. *Wavelet Transform*

Wavelet is a transformation that is almost similar with Forier Transform [8]. Forier transform is able to explain the signal singularity overally, but it is difficult to get the detail of failure at time domain. On the other hand, Wavelet Transform can effectively solve this problem since it can put at time domain. [9]

Wavelet is a family of functions generated by the basis wavelet ψ(x) called the mother wavelet [10]. Some examples of wavelet families are Haar, Daubechies, Symlets, Coiflets, BiorSplines, ReverseBior, Meyer, DMeyer, Gaussian, Mexican_hat, Morlet, Complex Gaussian, Shannon, Frequency B-Spline, Complex Morlet, Riyad, and so on [11].

$$WT_x(\alpha,\tau) = \frac{1}{\sqrt{\alpha}} \int x(t)\, \varphi^* \left(\frac{t-\tau}{\alpha}\right) dt = \{x(t), \varphi_{\alpha\tau}(t)\} \quad (1)$$

The equation $x(t) \in L^2(R)$, φ(t) is wavelet function. And {x,y} is defined as :

$$\{x(t), y(t)\} = \int x(t) y^*(t)\, dt \quad (2)$$

$\varphi\alpha\tau$ is defined as

$$\varphi_{\alpha\tau} = \frac{1}{\sqrt{\alpha}}\, \varphi \left(\frac{t-\tau}{\alpha}\right) \quad (3)$$

$\varphi_{\alpha c}$ Explains about integer factor widening and scale factor shifting of wavelet function. Function of t, α, φ is a continuous variable, so this method is then called as Continous Wavelet Transform. However, the signal has to be in discret before to analyze the data with a computer.

The wavelet bases used in testing arcing detectors at low voltages are as follows [12]:

1. Daubechies
   Ingrid Daubechies is one of the brightest stars in the field of wavelet research. The sieve length for all daubechies families is dBN = 2N, and the width is 2N-1. For example db2, the filter length is 4.
   The wavelet expansion of a signal x(t) has the following expression:

$$x(t) = \sum C_{j0k} \varphi_{j0k}(t) + \sum_{j=j0} \sum_{k} d_{ik} \psi_{jk}(t) \quad (4)$$

   Equation (4) shows that there are 2 terms. The first one is the '*approximation*' and the second one is the '*details*'. The details are represented by

$$d_{jk} = x(t)\, \psi(t)\, dt \quad (5)$$

2. Coiflets
   Coiflet wavelet functions its scaling function have 2N and 2N-1 moments equal to 0, respectively. The two functions have the support of length 6N-1[13]. The main indicative feature of coiflet wavelet is to have the highest number of vanishing moments for both scaling and wavelet function for given support width [14]. The approximation properties depend on the number of vanishing wavelet moments [15]. Let P_kF be an approximation of $f \in L^2(\Omega)$ on level k.

$$P_kF = \sum_{q \in ¢} \langle f, \phi_{k,q} \rangle\, \phi_{k,q} \quad (6)$$

   And for J<k

$$P_k F = \sum_{q\in Æ} \langle f, \phi_{J,q}\rangle \phi_{J,q} + \sum_{l=J}^{k-1} \sum_{q\in} \langle f, \mathfrak{f}_{l,q}\rangle \mathfrak{f}_{l,q} \quad (7)$$

3. Symlets
   Symlet wavelet has a short name sym, for order N written with SymN. The Symlet wavelet has order N=2,...,45. The filter length for the Symlet Wavelet is 2N.

III. DESIGN OF EQUIPMENT AND METHODS

This section describes the design, method, or approach used in answering research problems to achieve research objectives, as well as the stages of research in detail, briefly and clearly. The data collection process uses the STM32 microcontroller. In the data collection process, the serial arcing simulation module and the parallel arcing simulation module are used to generate the arcing phenomenon, and the STM32 microcontroller is connected to a current transformer (CT) through which the conductors pass to perform data acquisition. Data collection was carried out in 3 locations. The purpose of moving this data collection point is to see the effect of arcing on the load side current wave on the feeder side current wave.

A. *Design of Arcing Simulation Module*

In this study, a simulation of the phenomenon of arcing disturbances will be carried out using an arcing simulator module that uses a low voltage source of 220V and is connected to an incandescent light load. This arcing simulation module consists of a chamber box, incandescent lamp loads, switches, Miniature Circuit Breakers and current transformers. For data acquisition purposes, the current transformer will be connected to the STM32 microcontroller. The data received by the device will then be processed using the Dyadwaves software. The circuit and schematic of the series and parallel arcing simulation modules can be seen in Figures 3.1 and 3.2 below.

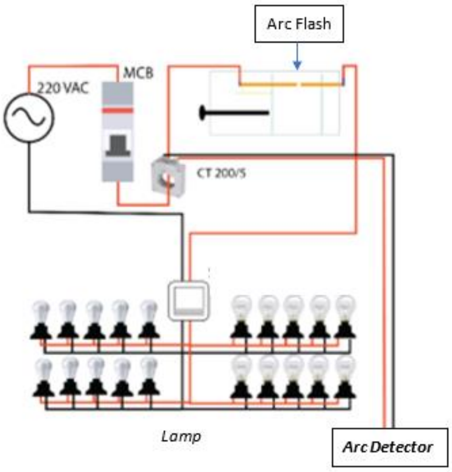

Figure 1. Series Arcing Simulation Module Schematic

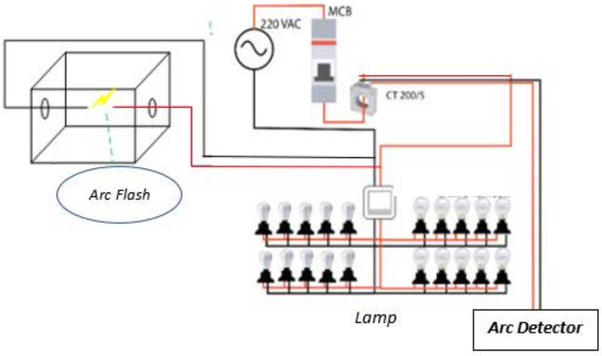

Figure 2. Schematic of Parallel Arcing Simulation Module

B. *Data Collection and Processing*

This section discusses the method of data acquisition or retrieval and processing used in this thesis. Data collection is divided into primary data collection to determine the method that can work well, and secondary data collection for data collection in 4 locations using the selected method.

1) *Primary Data Collection*

Primary data retrieval is the process of collecting data using the STM32 microcontroller and with a threshold value of 30. Threshold is a limit value that serves to distinguish arcing conditions from other conditions and will be used in arc detection programs as a reference value. In determining the threshold value, the threshold value must be above the highest original graph amplitude value and below the lowest arc peak value. This is because, the value above the peak of the original graph is the largest indicating that the area where the arc occurs. In the primary data collection process, a series arcing simulation module and a parallel arcing simulation module are used to generate arcing phenomena, and the STM32 microcontroller is connected to a current transformer (CT) through which it passes. Conductor to perform data acquisition..

Primary data collection was carried out in 3 locations, which will be explained in the subsection below. This transfer of data collection point aims to see the effect of arcing on the load side current wave on the feed side current wave.

At the time of serial arcing data collection, the simulation module will be powered on by a 220V source, then the MCB 16A is turned on. Lamp load variations are 400W, 700W, 1000W, and 1300W. Then, the switch is connected so that the light is on. To obtain data on arcing conditions, the distance between the electrodes is adjusted by using a rotary lever until series arcing occurs. The data from this process will be stored in a micro SD for later processing.

Furthermore, when parallel arcing data is taken, the simulation module will be powered on with a 220V source, then the 16A MCB is turned on. The variation in the number of filaments is 1 filament and 2 filaments. Then, the switch is connected so that the light is on. To obtain data on arcing conditions, one of the filaments is driven by a DC motor until the two filaments touch and arcing occurs. Stranded cable is a type of cable where the cable consists of several small wires (filaments) that are built together. Like solid cable, stranded cable has several copper strands (filaments) that form a single wire. The data from this process will be stored in a micro SD for later processing.

2) Secondary Data Collection

Secondary data retrieval is the retrieval of current signal data by using an arcing detection device that has been applied to the selected DWT method. Secondary data collection was carried out in 4 locations. The purpose of this data collection is to implement a detection tool using the DWT method that has been selected using a predetermined threshold value or limit according to the test data.

The mechanism or process for collecting secondary data is the same as the mechanism or process for collecting primary data. It's just that, in secondary data collection, it is also carried out at location 4 with a larger amount of power.

3) Data Collection Location

In this study, data collection was carried out at 4 different locations. The purpose of moving the data collection location is to determine the effect of arcing on the load side on the feeder, starting from the closest one, to the feeder on the SDP panel. The image below shows a single line diagram of the location of data collection and detection.

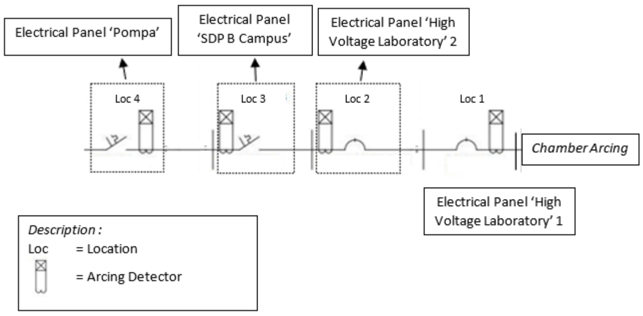

Figure 3. Single Line Diagram of Data Collection

4) Data Processing

Primary data processing aims to evaluate the wavelet transform method which has the highest level of accuracy and sensitivity. In this processing, the data in the form of current waves that have been acquired will be analyzed, using Dyadwaves software and 4 methods are compared to obtain and determine the most accurate method which will then be applied to arcing detectors for secondary data collection.

Secondary data processing is the process of knowing the performance of a predetermined detection method in detecting the occurrence of series arcing and parallel arcing. Data from the detector will be stored on the microSD and can be processed using the Dyadwaves software. Secondary data also shows whether arcing on the load side can be detected on the feeder side.

IV. Results and Discussion

A. Primary Data Collection Scheme

In this section, we will explain the primary data collection that will be used as an experiment and the data collection scheme from the three locations.

Table 1. Primary Data Retrieval Experiment Data

DATA	CONDITION	VARIABLE	NUMBER OF TRIALS EACH VARIABLE	NUMBER OF TRIALS
1	Series Arcing	400W	5x3 Location	15
		700W	5x3 Location	15
		1000W	5x3 Location	15
		1300W	5x3 Location	15
2	Parallel Arcing	1 Fiber	5x3 Location	15
		2 Fibers	5x3 Location	15
Total				90

The table above describes the amount of experimental data that will be taken. In table 4.1. Explains the existence of 2 conditions, namely arcing series and arcing parallel. When simulating series arcing faults, using a load variation of 400W, 700W, 1000W, and 1300W. When simulating parallel arcing disturbances, using variations in the number of filaments, namely 1 filament and 2 filaments.

The data collection scheme for each condition and each variable was carried out 5 times. So the total data collection is 90 data. Data collection was carried out in 3 different locations. The results of the data from the detector will be stored in the microSD and processed using the Dyadwaves software. The results of data processing from the Dyadwaves software will display 4 wavelet transform methods, namely Daubechies-1 (dB1), Daubechies-4 (dB4), Coiflet-4 (coif4), and Symlet-4 (sym4).

In this study, it will be investigated and analyzed which wavelet transform method has the highest level of accuracy and sensitivity to be used in the detector. The following is a sampling of the results of primary data collection for the occurrence of series arcing and parallel arcing.

B. Determination of Arcing Signal to Threshold Value

The process of the detector in determining the arcing signal is after the signal obtained from the CT is converted by the microcontroller into a DWT signal.

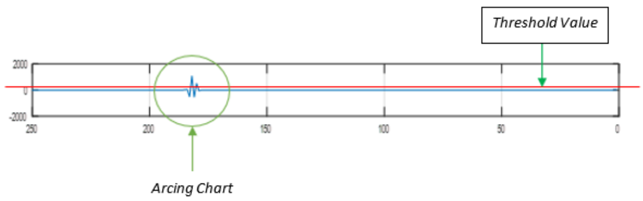

Figure 4. The Process of Arcing

From the graphic above, there is a red line as a predetermined threshold value. The graph is the current signal that comes from the CT and has been converted to a graph DWT by microcontroller.

This DWT graph will be compared with the threshold value. If there is an amplitude value that exceeds the threshold value, the tool will provide a sound indicator, and it will be displayed to the LCD layer as a sign of arcing. In the picture above there is a graph that exceeds the threshold value, it can be said that arcing has occurred.

C. Results of Primary Data Collection

The following is the result of the current signal when there is series arcing and parallel arcing and processed using 4 different methods using Dyadwaves software.

The top graph depicts the result of the original signal. The bottom graph explains the signal results that have become DWT. Y axis is Waveform Current (A), while X axis is Seconds (s).

1. Primary Data Arcing Series

The results of the arcing primary data series with a load variation of 400W, 700W, 1000W, 1300W after being processed using the Dyadwaves software as follows,

a. Daubechies-1

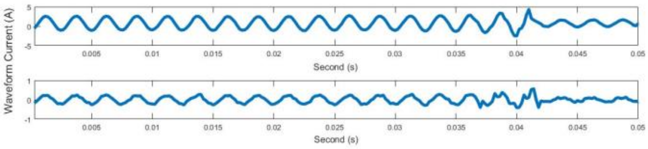

Figure 5. DWT Arcing Current series Signal Graph 400W Daubechies-1

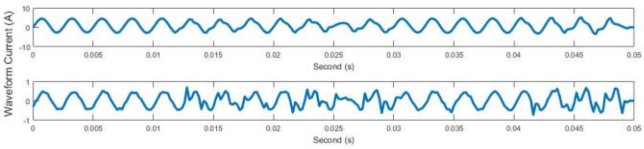

Figure 6. DWT Arcing Current Series Signal Graph in 700W Daubechies-*1*

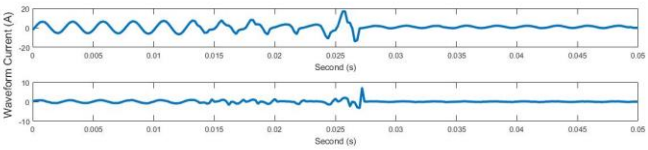

Figure 7. DWT Arcing Current Series Signal Graph 1000W Daubechies-1 .

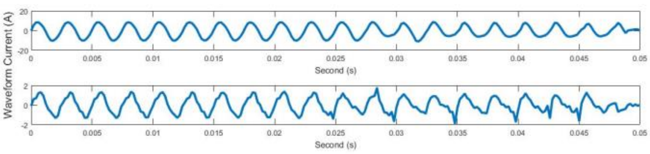

Figure 8. DWT Arcing Current Series Signal Graph 1300W Daubechies-1

b. Daubechies-4

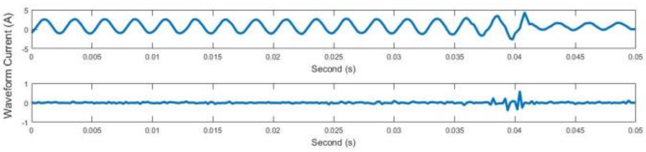

Figure 9. DWT Arcing Current Series Signal Graph 400W Daubechies-4

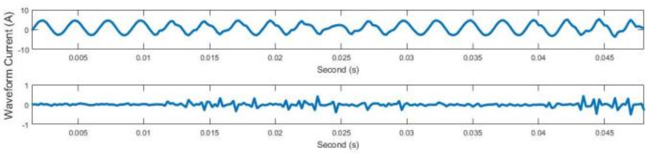

Figure 10. DWT Arcing Current Series Signal Graph 700W Daubechies-4

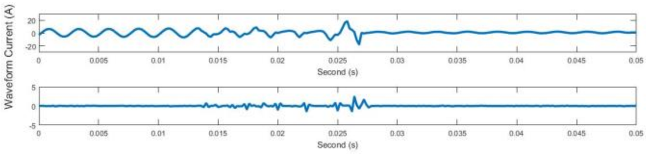

Figure 11. DWT Arcing Current Series Signal Graph 1000W Daubechies-4

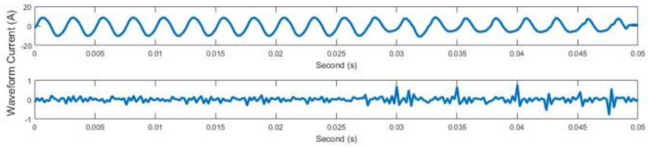

Figure 12. DWT Arcing Current Series Signal Graph 1300W Daubechies-4

c. Coiflets-4

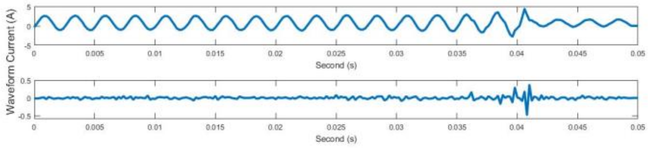

Figure 13. DWT Arcing Current Series Signal Graph 400W Coiflets-4

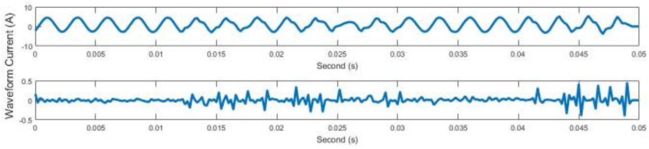

Figure 14. DWT Arcing Current Series Signal Graph 700W Coiflets-4

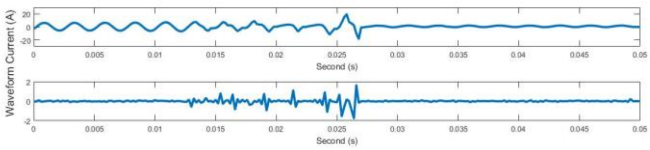

Figure 15. DWT Arcing Current Series Signal Graph 1000W Coiflets-4

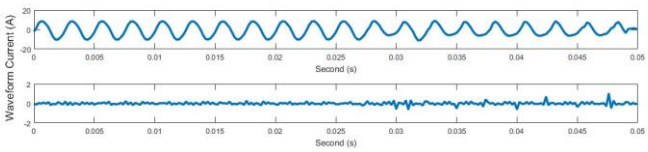

Figure 16. DWT Arcing Current Series Signal Graph 1300W Coiflets-4

d. Symlets-4

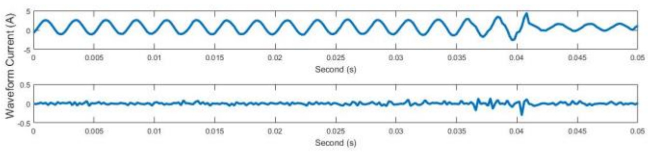

Figure 17. DWT Arcing Current Series Signal Graph 400W Symlets-4

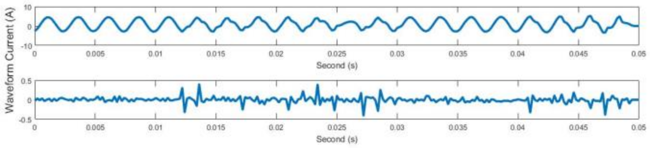

Figure 18. DWT Arcing Current Series Signal Graph 700W Symlets-4

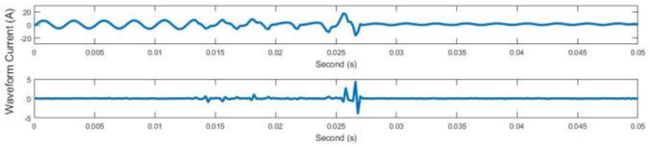

Figure 19. DWT Arcing Current Series Signal Graph 1000W Symlets-4

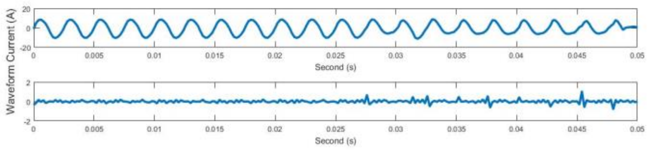

Figure 20. DWT Arcing Current Series Signal Graph 1300W Symlets-4

2. Primary Data Arcing Parallel

The results of parallel arcing primary data with variations in the number of 1 filament and 2 filaments after being processed using the Dyadwaves software are as follows:

a. Daubechies-1

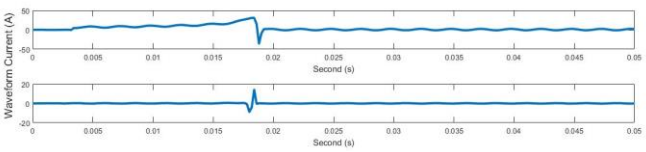

Figure 21. DWT Arcing Current Parallel Signal Graph 1 filament Daubechies-1

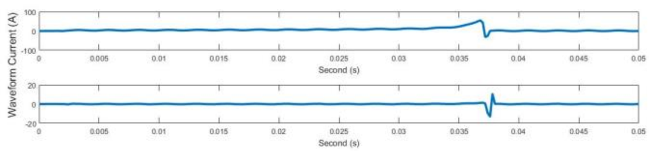

Figure 22. DWT Arcing Current Parallel Signal Graph 2 filaments Daubechies-1

b. Daubechies-4

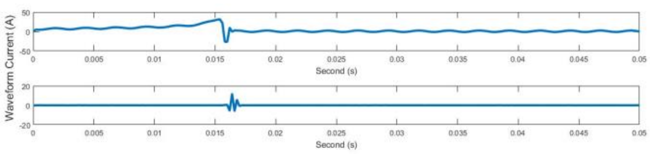

Figure 23. DWT Arcing Current Parallel Signal Graph 1 filament Daubechies-4

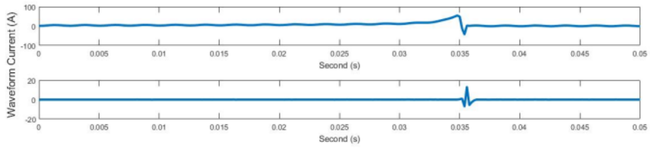

Figure 24. DWT Arcing Current Parallel Signal Graph 2 filaments Daubechies-4

c. Coiflets-4

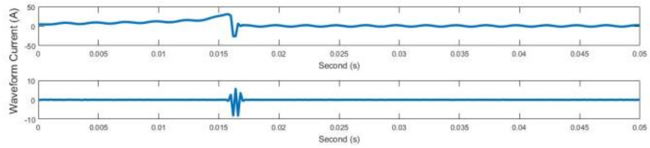

Figure 25. DWT Arcing Current Parallel Signal Graph 1 filament Coiflets-4

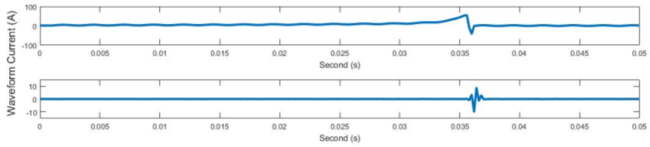

Figure 26. DWT Arcing Current Parallel Signal Graph 2 filaments Coiflets-4

d. Symlets-4

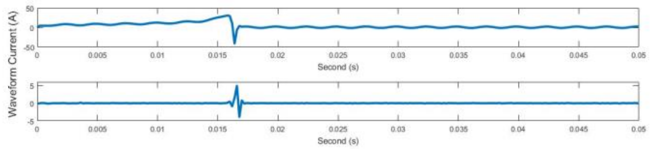

Figure 27. DWT Arcing Current Parallel Signal Graph 1 filament *Symlets-4*

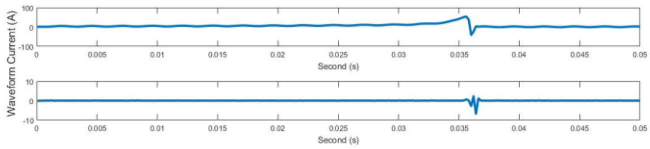

Figure 28. DWT Arcing Current Parallel Signal Graph 2 filaments *Symlets-4*

3. Analysis of the Wavelet Transform Method

In this section, the results of the analysis of the method of processing arcing current signal data will be presented after being converted to a DWT signal. The data is in the form of the peak of the highest amplitude in the DWT signal. The goal is to determine which method has a value above the threshold value. The higher the threshold value, the more accurate and sensitive the method is. The following is the result of the method data:

a. Series Arcing Signal Amplitude

The following will display the results of each method depicted in the form of a square with a different color. The blue color represents the 400W amount of power, the brown color represents the 700W amount of power, the gray color represents the 1000W amount of power, and the yellow color represents the 1300W amount of power.

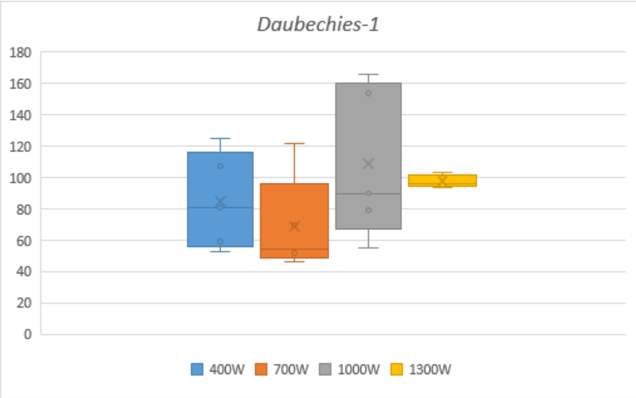

Figure 29. Series Arcing Amplitude *Daubechies-1*

Figure 30. Series Arcing Amplitude *Daubechies-4*

Figure 31. Series Arcing Amplitude *Coiflets-4*

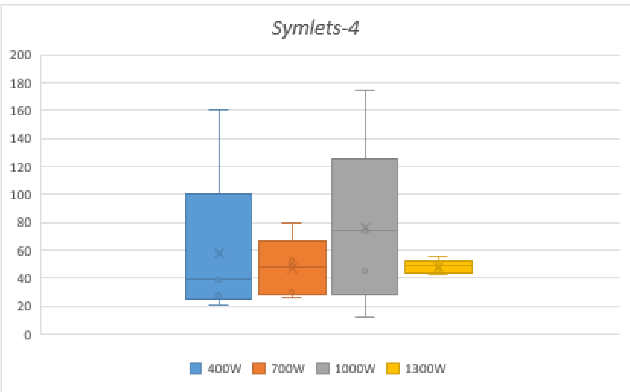

Figure 32. Series Arcing Amplitude *Symlets-4*

Tabel 2. Series *Arcing* Amplitude Value

No	Method	Total Load (W)	Amplitude Value (Trial to-)				
			1	2	3	4	5
1	Daubechies-1	400	125	81	107	59	53
		700	46	70	52	122	54
		1000	166	154	90	55	79
		1300	103	100	96	94	95
2	Daubechies-4	400	78,3	48,51	59,8	47,7	40
		700	62	57	109,12	108,6	40,1
		1000	65	86	60	46	48
		1300	55	54	53	48	50,1
3	Coiflets-4	400	46	45	56	40	44
		700	53	32	25	65	33
		1000	106	122	55	33	35
		1300	41	42	50	43	45
4	Symlets-4	400	160	39	41	21	28
		700	53	80	26	48	30
		1000	74	175	75	12	45
		1300	45	56	49	42	49

The graphs and tables above describe the amplitude value using 4 methods and 5 experiments were carried out for each load variation. In the Coiflets-4 and Symlets-4 methods there are values below the threshold. The amplitude value is the result of signal processing from the reading of the detector.

b. Amplitude of Parallel Arcing Signal

The following will display the results of each method depicted in a square with a different color. The blue color describes the number of 1 filament, the brown color describes the number of 2 filaments.

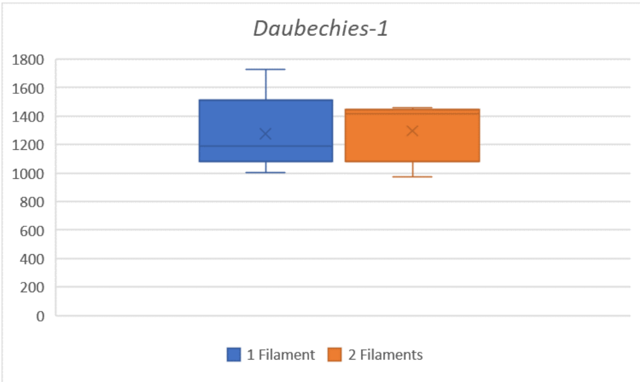

Figure 33. Parallel Arcing Amplitude *Daubechies-1*

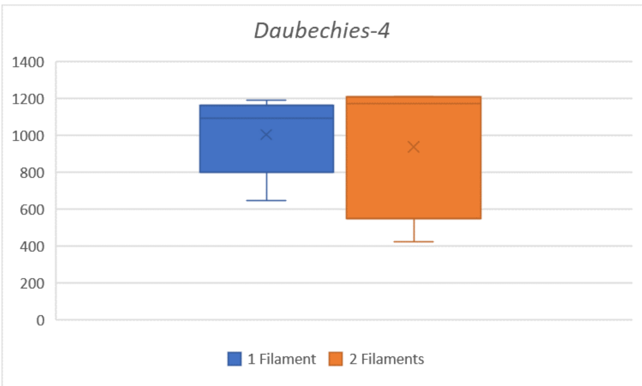

Figure 34. Parallel Arcing Amplitude *Daubechies-4*

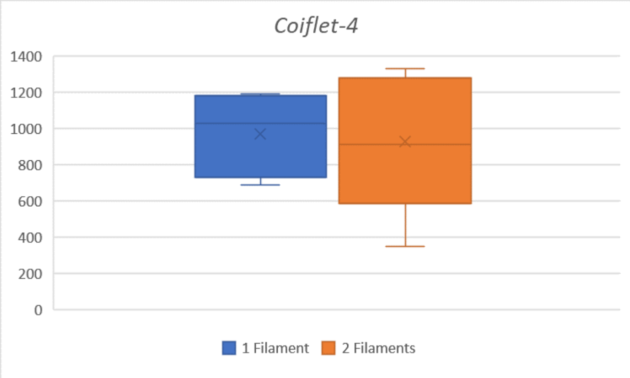

Figure 35. Parallel Arcing Amplitude *Coiflet-4*

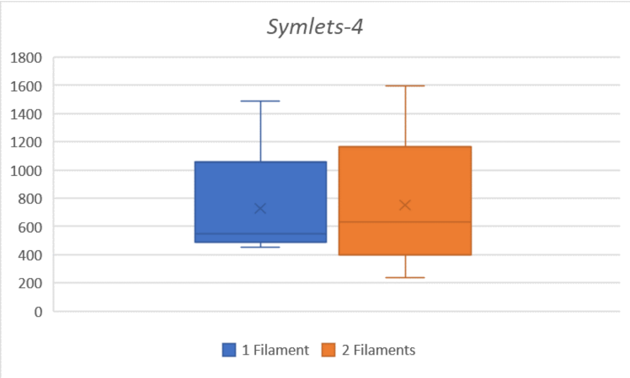

Figure 36. Parallel Arcing Amplitude *Symlets-4*

Tabel 3. Parallel Arcing Amplitude Value

No	Method	Number of Fibers	Amplitude Value (Trial to-)				
			1	2	3	4	5
1	Daubechies-1	1 Fiber	1187	1726	1003	1160	1295
		2 Fibers	1460	976	1418	1436	1187
2	Daubechies-4	1 Fiber	950	646	1133	1191	1094
		2 Fibers	670	1172	421	1203	1209
3	Coiflets-4	1 Fiber	687	1026	1173	1189	769
		2 Fibers	1231	821	349	1329	909
4	Symlets-4	1 Fiber	547	1488	522	628	455
		2 Fibers	1598	237	726	559	633

The graphs and tables above describe the amplitude values using 4 methods and the experiment was carried out 5 times for each variation in the number of filaments. In the parallel arcing detection test, all methods have an amplitude value above the threshold value.

Based on primary data collection and analysis, several conclusions are obtained regarding the wavelet transform method that will be used to detect arcing currents. The conclusions are as follows:

1. To detect series arcing,

a) It is not recommended to use the db1 method, because the normal signal amplitude value has a very high value close to the arcing signal amplitude value so that it will be difficult to determine the threshold value.

b) At low loads of 400W and 700W, the Coiflet-4 method and the Symlets-4 method have an amplitude value below the threshold value so that the method has a low level of accuracy.

2. To detect parallel arcing,

All methods have a high level of accuracy and sensitivity to detect parallel arcing faults. It can be concluded that the method that has the best level of accuracy and sensitivity that will be used for detection and secondary data retrieval is the Daubechies-4 wavelet transform method because the Daubechies-4 wavelet transform method has a very high arcing amplitude value and is far above threshold value.

D. Data Collection Scheme

In this subchapter, we will explain the secondary data retrieval using arcing detector using the Daubechies-4 wavelet transform method. The data collection scheme is carried out in 4 locations.

Tabel 4. Secondary Data Retrieval Experiment

DATA	*CONDITION*	*VARIABLE*	*NUMBER OF TRIALS EACH VARIABLE*	*NUMBER OF TRIALS*
1	Series Arcing	400W	5x4 Location	20
		700W	5x4 Location	20
		1000W	5x4 Location	20
		1300W	5x4 Location	20
2	Parallel Arcing	1 Fiber	5x4 Location	20
		2 Fibers	5x4 Location	20
Total				120

The data collection scheme for each condition and each variable was carried out 5 times. So the total data collection is 120 data. Data collection was carried out in 4 different locations. The results of the data from the detector will be stored in the microSD and processed using the Dyadwaves software.

In testing the detector using the Daubechies-4 wavelet transform method, it will measure the success rate of the arcing detector. The success of the detector can be determined by whether the device can detect faults in series arcing or parallel arcing in 4 different locations. Following are the results of secondary data collection for the detection of series arcing and parallel arcing in 4 locations. The following is a sampling of the results of secondary data collection for the occurrence of series arcing and parallel arcing.

E. Results of Secondary Data Collection

In this subchapter, the test results for serial arcing and parallel arcing will be shown using the Daubechies-4 method. Testing of the detectors was carried out in 4 different locations. If there is an amplitude value that exceeds the threshold value, the detector will make a sound and will display an arcing notification on the LCD.

The following is a table of the success of the arcing detector using the selected Daubechies-4 method, In the results of tests carried out in 4 locations. The trial was carried out by simulating the presence of series arcing and parallel arcing faults. In the table above, it can be concluded that by using a detector with the Daubechies-4 method, the detector can work and detect well with a 100% success rate when used to detect parallel arcing faults.

When used to detect series arcing, the detector does not work optimally. At locations 1,2, and 3, the detector can work well, but when it is used to test at location 4, the detector cannot detect it. This means that arcing detectors do not work optimally when used on larger feeders or feeders with high loads.

Table 5. Arcing Detector Series Success Rate

Condition	Total Load (W)	Trial to-	Level of Success			
			Location 1	Location 2	Location 3	Location 4
Series Arcing	400	1	Detected	Detected	Detected	Not detected
		2	Detected	Detected	Detected	Not detected
		3	Detected	Detected	Detected	Not detected
		4	Detected	Detected	Detected	Not detected
		5	Detected	Detected	Detected	Not detected
	700	1	Detected	Detected	Detected	Not detected
		2	Detected	Detected	Detected	Not detected
		3	Detected	Detected	Detected	Not detected
		4	Detected	Detected	Detected	Not detected
		5	Detected	Detected	Detected	Not detected
	1000	1	Detected	Detected	Detected	Not detected
		2	Detected	Detected	Detected	Not detected
		3	Detected	Detected	Detected	Not detected
		4	Detected	Detected	Detected	Not detected
		5	Detected	Detected	Detected	Not detected
	1300	1	Detected	Detected	Detected	Not detected
		2	Detected	Detected	Detected	Not detected
		3	Detected	Detected	Detected	Not detected
		4	Detected	Detected	Detected	Not detected
		5	Detected	Detected	Detected	Not detected

Table 6. Arcing Detector Parallel Success Rate

Condition	Number of Fibers	Trial to-	Level of Success			
			Location 1	Location 2	Location 3	Location 4
Parallel Arcing	1 Fiber	1	Detected	Detected	Detected	Detected
		2	Detected	Detected	Detected	Detected
		3	Detected	Detected	Detected	Detected
		4	Detected	Detected	Detected	Detected
		5	Detected	Detected	Detected	Detected
	2 Fibers	1	Detected	Detected	Detected	Detected
		2	Detected	Detected	Detected	Detected
		3	Detected	Detected	Detected	Detected
		4	Detected	Detected	Detected	Detected
		5	Detected	Detected	Detected	Detected

V. Conclusion

Based on the testing, data processing, and analysis of the test results that have been carried out, several conclusions were obtained regarding the wavelet transform method for detecting arcing currents. The conclusions are as follows: To detect series arcing, the results of the graph using the Daubechies-1 method have a very high amplitude value close to the arcing signal amplitude value, so it will be difficult to determine the threshold value.

The results of the graph using the Coiflet-4 and Symlet-4 methods, there is an amplitude value below the threshold value so that the method has a low level of accuracy. To detect parallel arcing all methods Daubechies-1, Daubechies-4, Coiflet-4, and Symlet-4 are very well used to detect parallel arcing and have a high level of accuracy and sensitivity. The Daubechies-4 method is very good for detecting series arcing and parallel arcing because the normal signal amplitude value has a very high difference with the arcing signal amplitude value, and makes it easier to determine the threshold value so that the method has a high level of accuracy and sensitivity. After testing the detection of parallel arcing in 4 locations, the Daubechies-4 method has a 100% success rate. When used to detect series arcing faults at locations 1,2,3, the Daubechies-4 method worked optimally and very well, but when testing was carried out at location 4, the detector did not work optimally.

In this study, an evaluation of the use of mother wavelets with the Discrete Wavelet Transform (DWT) method in low voltage detection equipment has been carried out. Testing of the selected method, namely Daubechies-4 (dB4) has been carried out at each location, but with accuracy that is not optimal when used for serial arcing detection in feeders with larger loads. Therefore, it is necessary to make improvements to both hardware and software components, so that they can be used optimally on all sides of the feeder (main feeder).

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