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# Partial discharge signal denoising by using hard threshold and soft threshold methods and wavelet transformation

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# Partial discharge signal denoising by using hard threshold and soft threshold methods and wavelet transformation

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**Abstract**. The important thing to do after we detect the existence of partial discharges inside an isolation system is signal processing. One form of signal processing that needs to be carried out on the generated waveform is denoising or noise removal from the wave obtained. In this study, an experiment will be conducted to denounce partial discharge waves using Wavelet and Threshold transformations. Wavelet transformation is applied in various levels then we compare the best denomination while denoisation using Threshold is applied using Soft Threshold and Hard Threshold.

## 1. Introduction

In partial discharge measurement techniques using UHF (Ultra High Frequency) sensors, partial discharge signals are obtained in the form of high electromagnetic frequency waves. Therefore, many methods currently use to process these high-frequency signals to get an accurate interpretation of equipment isolation conditions. Several signal processing methods that have been developed until now are Phase Resolved Partial Discharge (PRPD), Frequency Spectrum Analysis, Time Domain Waveform analysis, Envelope Detection analysis and so on.

In general, the methods for processing the partial discharge signal are carried out based on the principle of Fourier Transformation in the frequency domain or in the time domain. However, the use of this transformation has a weakness because when doing wave analysis in the time domain, data information from the frequency domain is lost as well as vice versa. Therefore, it is necessary to develop a partial discharge signal processing method that can provide signal information in the frequency domain and time domain at once.

In this study, an experiment will be conducted to create an application program to derive partial discharge signals by using Wavelet Transformation and Threshold. Application programs are created using Matrix Laboratory (Matlab). The experiment was carried out by first detecting partial discharge using an RC detector that was integrated with the computer and then we took the data in the form of CSV from the obtained signal. The data will then be processed using the application program that has been created.

## 2. Basic Theory

### *2.1. Partial Discharge*

The basic nomenclature regarding Partial Discharge is found in the International Electrotechnical Commission (IEC) 60270: 2000 standard. Under this standard partial discharge is an electrical phenomenon locally which partially connects the isolation between the conductors and occurs either on the surface of the conductor or inside the conductor (void). Partial discharge occurs due to the non-homogeneous field in the insulator [1].

Based on data obtained from electric power systems in several countries in the world, it is known that the failure of the isolation system causes almost 84% of the damage that occurs in transformers, while the Switchgear reaches 95% and the power cable reaches 89% [2]. Therefore the condition of insulators in high voltage equipment must be monitored regularly using effective methods.

Partial discharge detection is one of the most effective methods for monitoring isolation conditions. Detection of PD existence and monitoring system for the diagnosis of high voltage equipment has been developed to date [3 - 7]. Since the 1990s, pattern identification methods have been applied in Partial discharge identification replacing the identification method of visual assessment of debit charts.

### *2.2. Threshold*
The first method for the signal denomination in this study is Threshold. The threshold is a process for removing values that are smaller than the threshold that has been set. One of the quantities that can be used as a threshold value on the signal that is deregulated using this method is the amplitude of the signal. There are two functions of threshold that will be used in signal processing in this research that is Hard Threshold and Soft Threshold.

### *2.3. Wavelet Transformation*
Wavelet transformation is the development of Fourier transform. Given the weaknesses of Fourier transforms that can only provide signal processing results in one domain only (between frequency and time), this wavelet transformation becomes a transformation that can provide good frequency and time resolution simultaneously. Wavelet transformation is a conversion function that can be used to divide a function or signal into different frequency components, which are then studied according to the scale.

Two wavelet transformation methods can be used in processing these signals, namely Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT). In this study, the wavelet transformation used is the DWT method. This is because the data we use in this study is a CSV file whose original form is discrete data from voltage amplitude with time.

Signal denoising process with wavelet transformation that will be carried out in this research can be seen in the following figure.

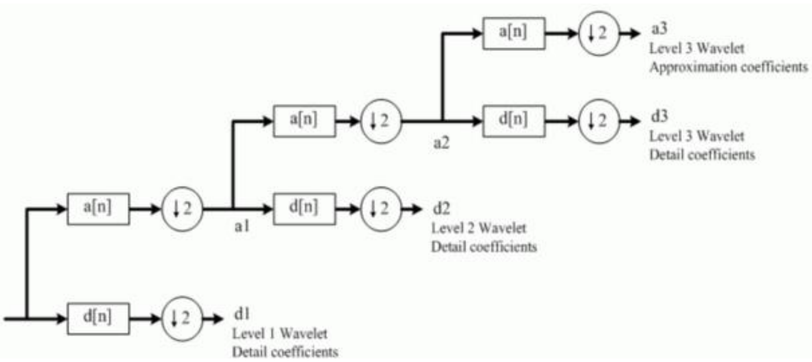


**Figure 1**. Denoising Process with Wavelet.

## 3. Design and Making of Applications
Application of wavelet transformation will be made using Matlab R2012a software that already supports the GUI (Graphical User Interface) so that the application we make can be more interesting and friendly to the user because only click the input data and then choose the process to be done. The output obtained is in the form of graphs of input and output signals in the form of graphs that can be

extracted in the form of CSV files to facilitate us in analyzing the comparison between the input and the obtained signal. The following is a display of the application that was created

The specifications of the wavelet transformation application that have been made in this study are as follows:

- Input is a PD signal data in CSV format obtained from the measurement
- The app will display a discrete form of the input waveform
- Once given a signal processing command, the application will display a discrete form of the output waveform
- The output of this application can be extracted in CSV format so that it can be used as input for the next process

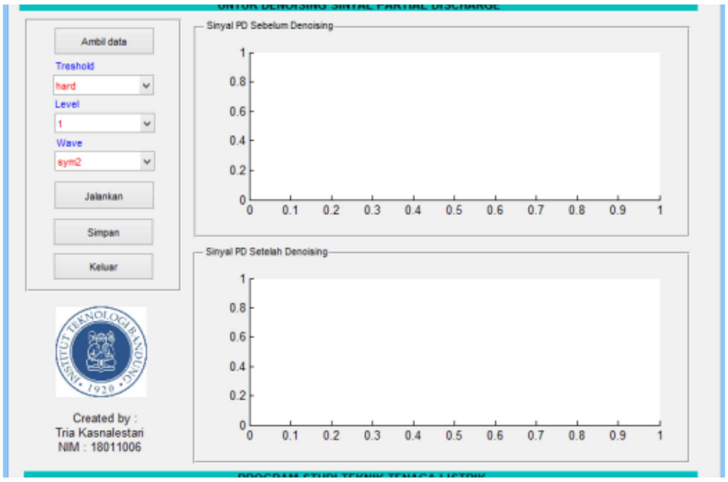


**Figure 2**. Display of Application That Has Been Made.

## 4. Testing Applications and Analysis

This application will be tested by simulating two wavelet parameters, namely threshold, and leveling. Before the test, it was taken to take some data from the partial discharge signal using a measurement circuit based on IEC 60270 using the plate and sensor needle media and the sensor of an RC detector. The following figure shows the circuit used for measurement.

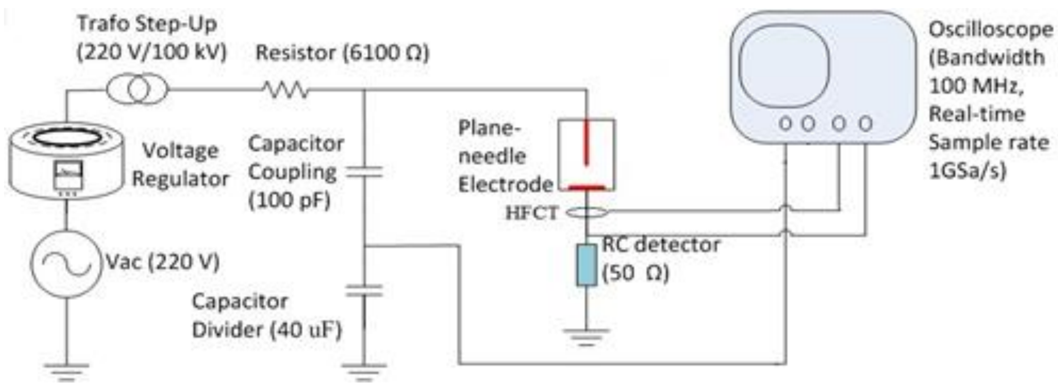


**Figure 3**. PD Measurement Circuit.

### *4.1. Threshold Parameter Testing*

The test was carried out by using the Soft Threshold and Hard Threshold of 4 partial discharge wave data. From the results of this test, we can compare which method is better in denoisation partial discharge waves. Following are the results of testing the threshold parameters.

#### *4.1.1. SignalPD_1*

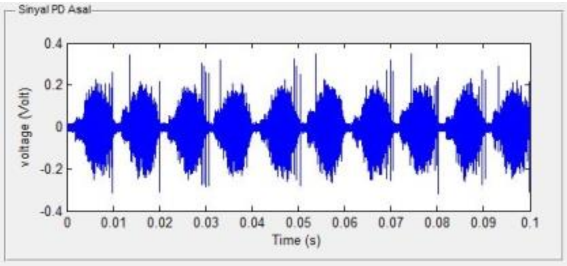


**Figure 4**. PD signal origin / before denoising.

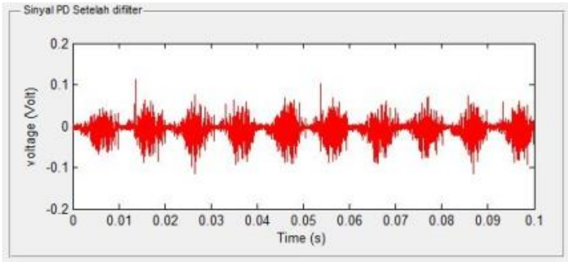


**Figure 6**. PD signal after denoising with the soft threshold.

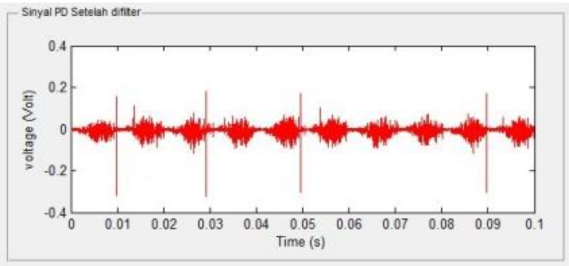


**Figure 5**. PD signal after denoising with the hard threshold.

#### *4.1.2. SignalPD_2*

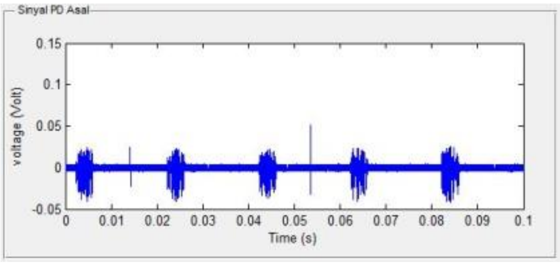


**Figure 7**. PD signal origin / before denoising.

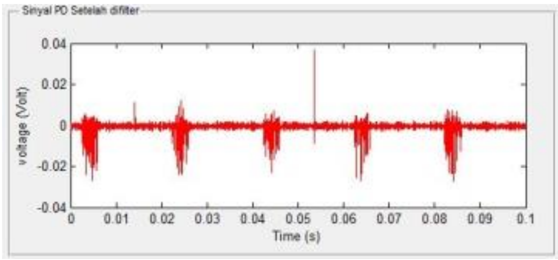


**Figure 9**. PD signal after denoising with the hard threshold.

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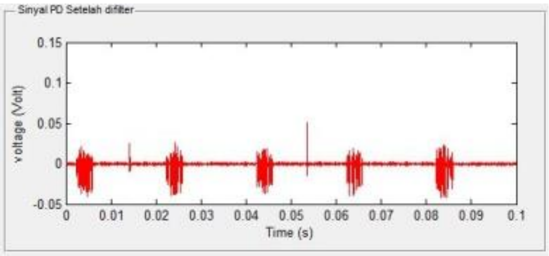


**Figure 8**. PD signal after denoising with the hard threshold.

*4.1.3. SignalPD_3*

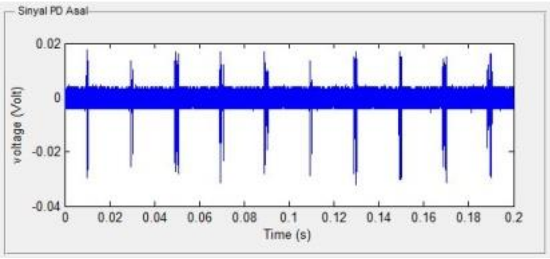


**Figure 10**. PD signal origin/ before denoising

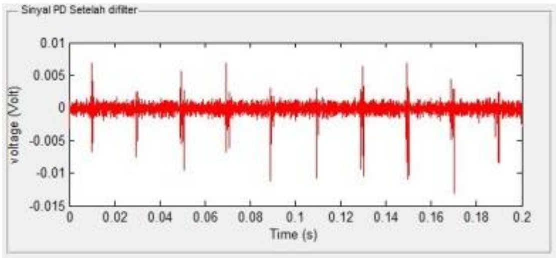


**Figure 12**. PD signal after denoising with the soft threshold.

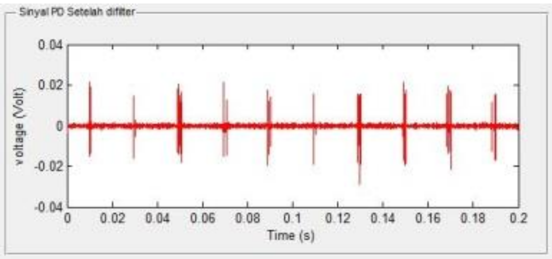


**Figure 11**. PD signal after denoising with the hard threshold.

*4.1.4. SignalPD_4*

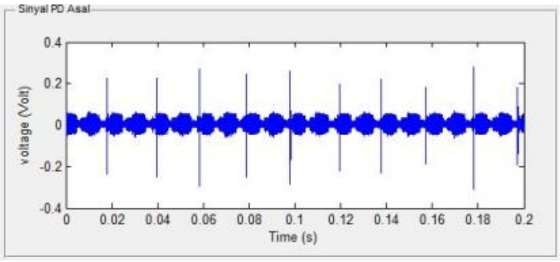


**Figure 13**. PD signal origin/ before denoising

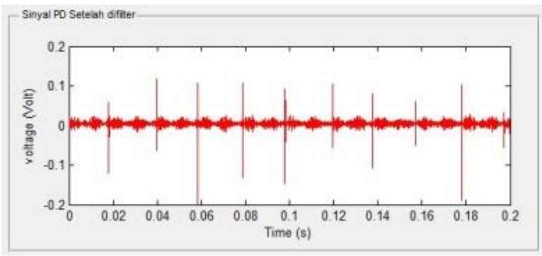


**Figure 15**. PD signal after denoising with the soft threshold.

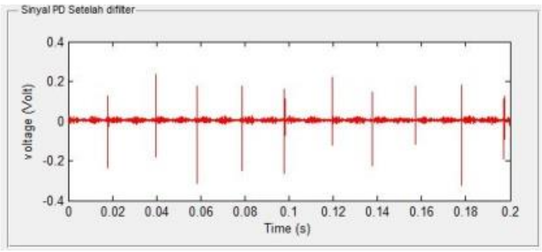


**Figure 14**. PD signal after denoising with the hard threshold.

The analysis on this test can be done visually through the generated graph or the csv data obtained. Based on the visual analysis we can see that the results of denoising using the soft threshold give relatively better results than the hard threshold. This can be seen from the signal amplitude given by the soft threshold in all tests giving a smaller value than the amplitude value obtained from the hard threshold. This can happen because in testing the wavelet transformation with the soft threshold parameter all input values undergo a modification process where the input value that exceeds the threshold is reduced by the threshold parameter value while the input value less than the negative threshold will be added to the parameter value and the other value will be changed to zero.

After we compare the output visually, then we can find the SNR (Signal to Noise Ratio) ratio of each Partial Discharge wave. The following table presents the SNR comparison of each PD signal to the soft threshold and hard threshold output.

**Table 1**. results of SNR threshold parameters.

| No | Signal | Threshold Mode | SNR before denoising (dB) | SNR after denoising (dB) |
|---|---|---|---|---|
| 1 | SignalPD_1 | Hard | 13.7 | 19.5 |
| | | Soft | | 23.5 |
| 2 | SignalPD_2 | Hard | 28.7 | 28.8 |
| | | Soft | | 31.5 |
| 3 | SignalPD_3 | Hard | 37.0 | 35.1 |
| | | Soft | | 45.1 |
| 4 | SignalPD_4 | Hard | 16.0 | 17.5 |
| | | Soft | | 24.5 |

From the table above, we can see that based on the SNR results, the soft threshold method can provide better results than the hard threshold. This can be seen from the soft threshold SNR value which is greater than the hard threshold SNR.

### *4.2. Level Parameter Testing*

In this test, the experiment will be carried out by inputting one of the PD values that have been obtained into the application program and generated a level 1 wavelet transformation on the waveform. Then this level 1 output will be inputted back into the application program to obtain level 2 wavelets. This is repeated until we get to level 6 wavelets.

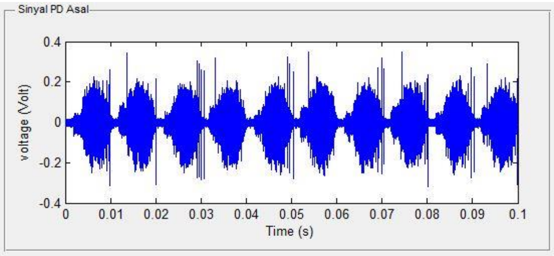


**Figure 16**. The original signal of PD

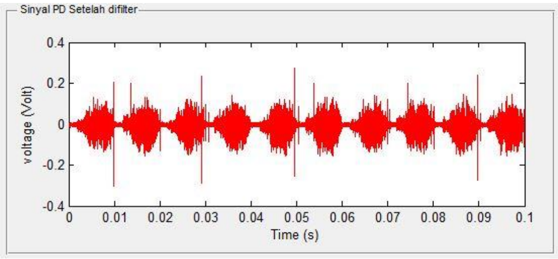


**Figure 17**. PD signal denoising with level 1

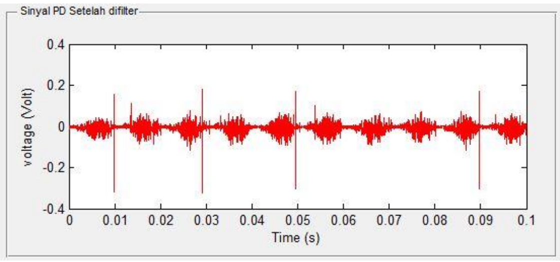


**Figure 18**. PD signal denoising with level 2.

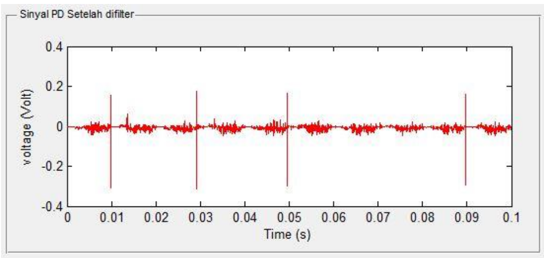


**Figure 19**. PD signal denoising with level 3.

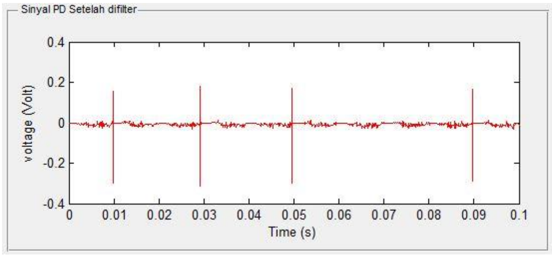


**Figure 20**. PD signal denoising with level 4.

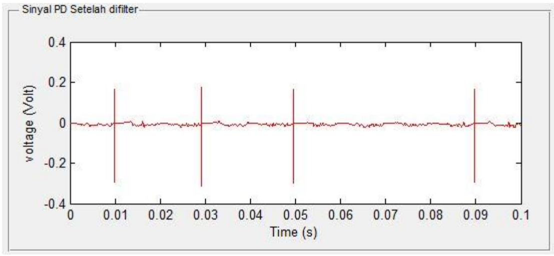


**Figure 21**. PD signal denoising with level 5.

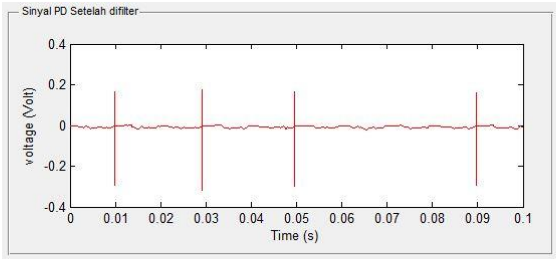


**Figure 22**. PD signal denoising with level 6.

Based on the graph of the simulation results, we can see visually that as the wavelet level increases, the number of noise decreases. This is because the signal is continuously inserted into the filter so that the amount of noise muted will be more and more. From the data obtained, we can know that wavelet level 6 provides the best results for denoising signals.

SNR analysis is done by comparing SNR from input to SNR of wavelet result of each level. The following table presents the SNR comparisons for each level.

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**Tabel 2**. Hasil SNR parameter level wavelet.

| Level Wavelet | Threshold | SNR before denoising (dB) | SNR after denoising (dB) |
|---|---|---|---|
| 1 | Hard | 13.7 | 15.7 |
| 2 | | | 19.5 |
| 3 | | | 19.6 |
| 4 | | | 19.6 |
| 5 | | | 19.6 |
| 6 | | | 19.7 |

The SNR results also show a similar thing to the previous analysis. This is evidenced by the increase of SNR value for every increase of wavelet level and the best SNR value obtained for wavelet level 6.

## 5. Conclusion

The following conclusions can be drawn as follows:

- Wavelet transformation can be applied to derogate partial discharge waves
- The soft threshold wavelet method provides better results than the hard threshold
- The SNR value for each increase in wavelet level is greater so that testing using higher level wavelet gives higher signal denoising

## References

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