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CLASSIFYING THREE TYPES OF PARTIAL DISCHARGES BY DIFFERENT FEATURES USING DIFFERENT STRATEGIES

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Abstract- Transformers must be monitored continuously and damaging discharge must be detected reliably too. Three important types of Partial Discharge (PD) defects that may occur in high voltage equipment are corona, surface discharges and discharges in the insulation cavities. These three signals are different in some attributes. In this paper we are looking for properties that are significant and distinguishing in comparison. Three different strategies will be used for achieving admissible results. It must be noted that for denoising, the wavelet functions will be used, based on two methods [2, 3].

Keywords: Partial Discharge (PD), Corona Discharge, Surface Discharge, Cavity Discharge, Denoising, Wavelet, Classifying, Feature Extraction.

I. INTRODUCTION

Mounting capacitive sensors on the surface of the bobbin is one of the most effective methods to track the partial discharge and to recognize fault type for dry distribution transformers. By detection of the partial discharge signals through the capacitive sensors, it is possible to find the location and type of the partial discharge [5, 6]. In this article these 3 types of PD will be study, which are the most occurred in transformers. These 3 signals, are different in some attributes, although there are similar in some else's. So we focus on the differences to classify them.

It is clear how the differences will be more, the accuracy of classification will be better. These features are useful in comparison. In other word, it is impossible to identify a signal and classify it by using these features when there aren't more signals for comparison. To classify signals, three signals are needed at least. So by applying strategies, mentioned in this article, and using features, differences of signals will be clear, and classification can be done [5].

II. PARTIAL DISCHARGE TEST CONDITIONS

By using a test circuit including two electrodes, artificial partial discharge defects will be produced (Figure 1) and each of them will be saved. For example to simulate the corona in air, the electrode needle - plate can be used. By applying the voltage to the electrodes, the corona will be occurred in needle electrode.

Table 1. Partial discharge test conditions

		Test 1	Test 2	Test 3
Calibration		167 pC	400 pC	1970 pC
Primary side voltage		105 V	165 V	165 V
Calibration and measurement	G20dB	on	on	off
	GPD	50	0	20

III. MODEL OF SIGNALS DEFINED BY DIFFERENT STRATEGIES

In this paper we are looking for properties that are significant and distinguishing in comparison. That is a feature of the partial discharge signal is extracted. But this feature has the power of diagnosing the various signals only when the signals compared under the same conditions. At first, some signals have been produced in laboratory conditions, which mentioned in Table 1 (Figure 1). For example, the corona signal has been generated in 3 different conditions, and repeated 10 times for each test. So we have 30 signals for corona discharge in 3 categories.

The three strategies for feature extraction are:

1- Signal did not denoised and the investigations are on the signal with white noise to extract distinguish features to classify PDs.

2- Signal is denoised, but no other changes will be applied to residual signal. There are many ways of denoising, and among them, Wavelet is one of the most effective method. In this paper, two methods, maximum likelihood and minimum least square, are used in order to decide the best wavelet function for denoising, emphasizing on two different artificial discharge signals.

The first way is called Maximum Likelihood and the second is named Minimum Least Square. In the first proposed method, the correlation between the denoised signal and original signal gives a likelihood coefficient. The closer likelihood coefficient to one, the better selected wavelet function will be. In the second method, the denoised signals are deducted from the original signals, and the relevant residue is considered. The less residue, the better denoising will be resulted.

3- Signal is denoised and some changes will be applied to residual signal. This change means that the output will be zero under some circumstances. Here, if signal values enter to 2% of maximum output value; the output value of signal will be zero. Implicitly we call these signals, the varied signals. (Figure 5(c), Figure 6(c) and Figure 7(c)).

The methods that have been used for optimum selection of the wavelet function in order to omit the noise are as follows [1, 4]:

1) First, the original signal has been denoised by the specified wavelet function.

2) At this step, second norm of the difference between original signal and denoised signal is obtained. It is obvious that the smaller the second norm magnitude, the better the selected wavelet function.

3) After receiving partial discharge signal, it is denoised with 37 wavelet functions and at 5 levels and step 2 and 3 are done.

Here, surface discharge denoising is delivered For example. At this experiment, partial discharge resulted from a needle and insulated plate was measured. By using wavelet functions for denoising and applying above mentioned methods as it is seen in Table 2, values of the difference between the original and the denoised signal resulted from applying wavelet functions No. 11, 21, 41, 46, 56, 86, 126, 136, 141, 171, 176 are the smallest. Table 3 shows the correlation coefficients between the original and the denoised signal. As it is seen, the correlation coefficients regarding wavelet functions No. 11, 21, 41, 46, 56, 86, 126, 136, 141, 171, 176 have greater values than others. Figure 2 shows original signal and denoised signal resulted from level 4 bior2.8, level 4 rbio2 2.6, level 4 rbio2 2.8, level 4 sym6 wavelet functions. Also it is recommended not to use rbio2 3.1 wavelet functions. The wavelet functions mentioned below are offered to be used for surface discharge [1].

1) coif2, L: 4	2) bior2.8, L: 4	3) rbio2 2.6, L: 4
4) rbio2 5.5, L: 4	5) rbio2 6.8, L: 4	6) rbio2 2.8, L: 4
7) bior6.8, L: 4	8) sym8, L: 4	9) sym6, L: 4
10) db6, L: 4	11) db4, L: 4	(L: Level)

In Figure 5 corona discharge signal has been showed in models of three strategies. Figure 5(a) refers to model, made by strategy 1, Figure 5(b) refers to model, made by strategy 2, and Figure 5(c) refers to model, made by strategy 3. Also Figure 6(a), (b) and (c) refer to surface discharge models, made by strategies 1, 2 and 3 and Figure 7(a), (b) and (c) refer to models of discharges in the insulation cavities, made by strategy 1, 2 and 3 [1, 4].

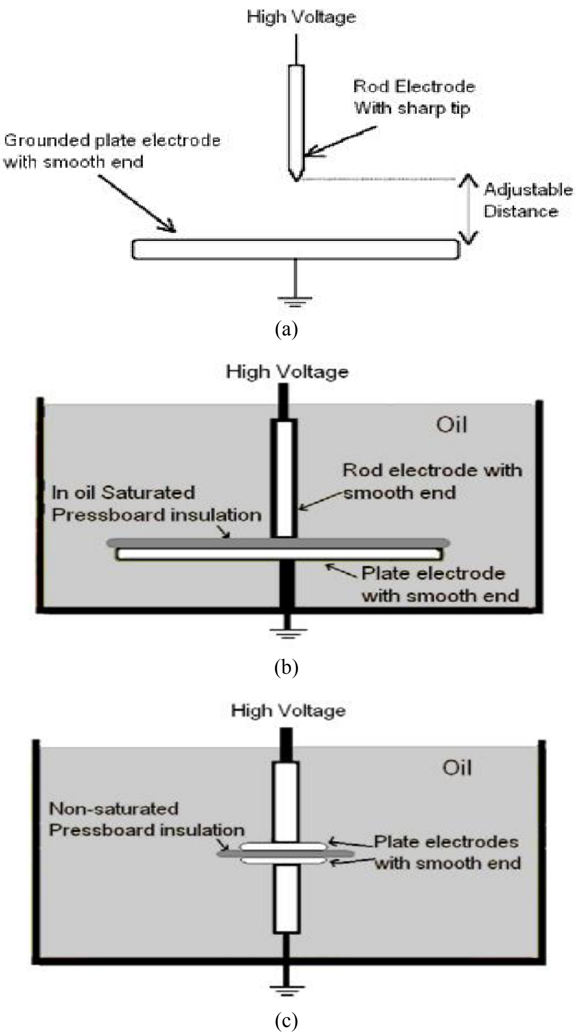
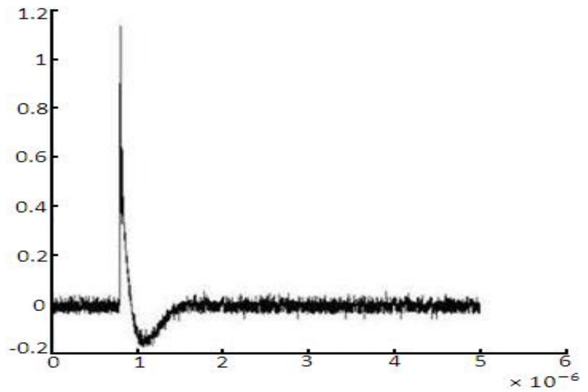


Figure 1. Different arrangements of various kinds of partial discharge
(a) Discharge of the holes inside insulation (b) Corona (c) Surface discharge Schematic of the measurement system with ultra wideband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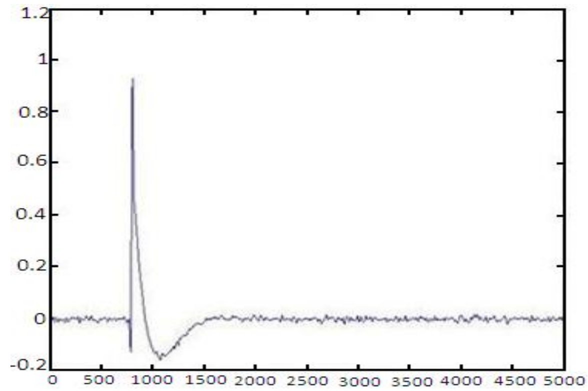
× 10⁻⁶

(a)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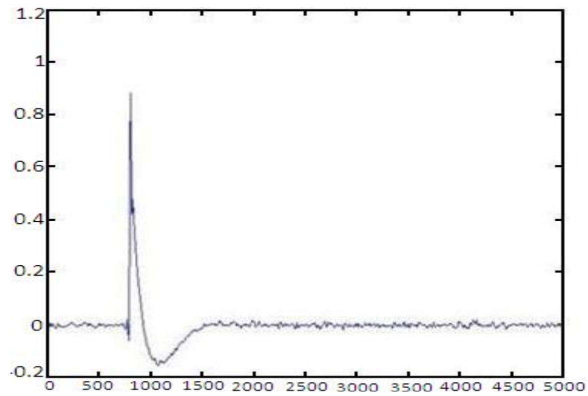
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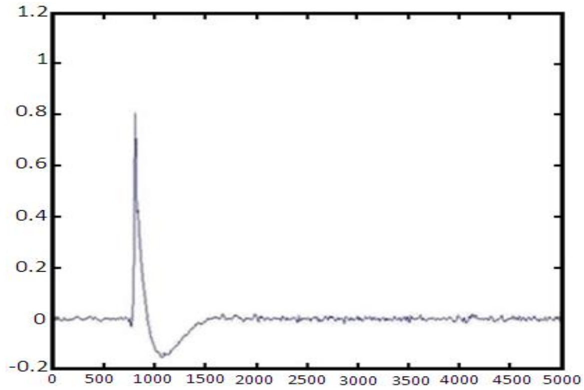
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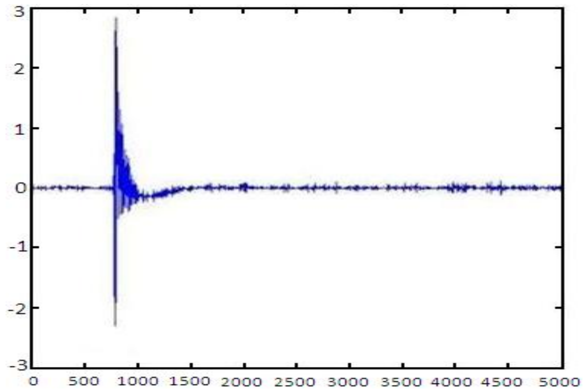
(d)



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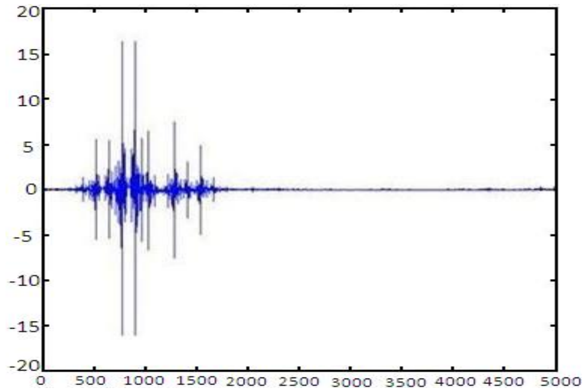


(f)

Figure 2. Surface discharge signals
(a) Origin signal
(b) Denoised signal by bior2.8, level4
(c) Denoised signal by rbio 2.6, level 4
(d) Denoised signal by rbio2 2.8, level4
(e) Denoised signal by sym6, level
(f) Denoised signal by rbio2 3.1, level 8

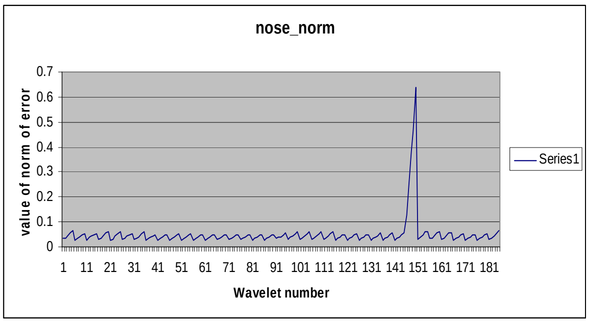


Figure 3. Second norm of the difference between main signal and denoised signal

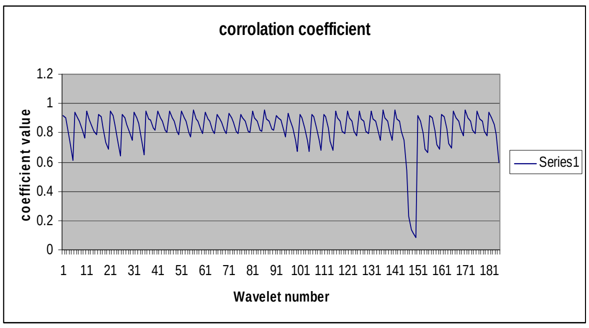
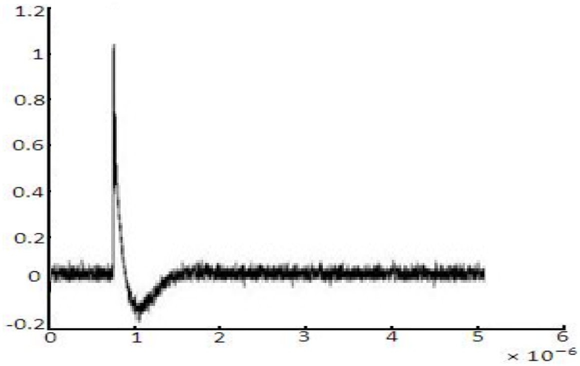
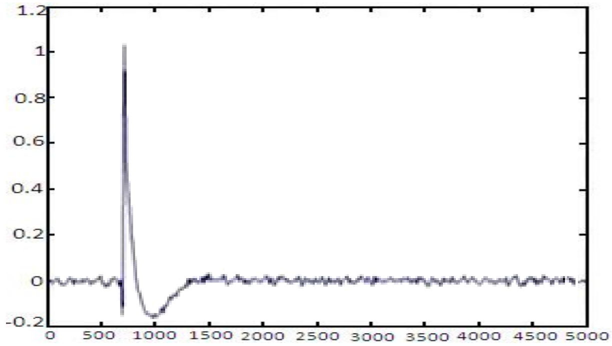


Figure 4. The coefficients between main signal and denoised signal



(a)



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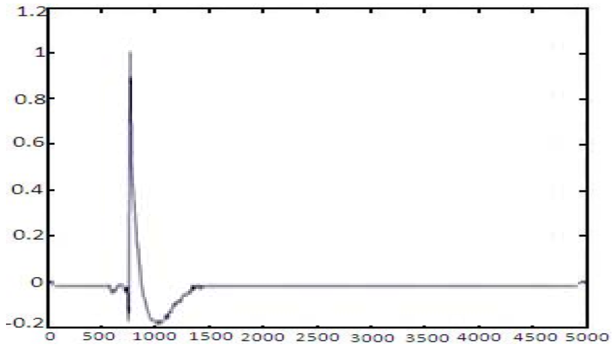


(c)

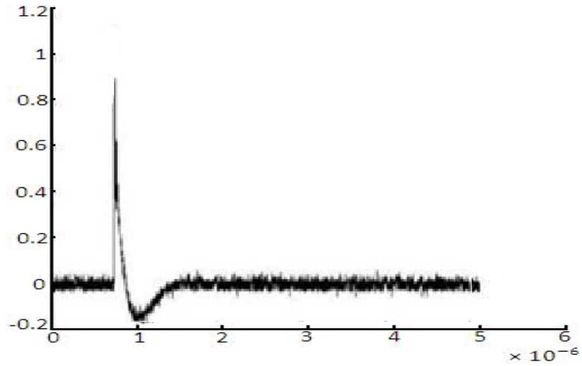
Figure 5. Corona discharge signals
(a) Origin signal
(b) Denoised
(c) Varied signal

Table 2. The value of second norm of the difference between main signal and denoised signals with selected functions

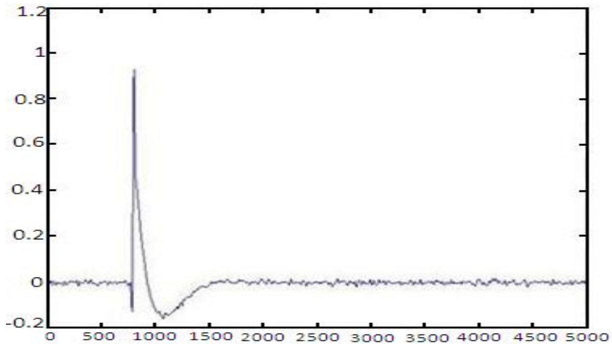
Wavelet function	Test 1	Test 2	Test 3
11	0.0258	0.0257	0.0256
21	0.0260	0.0262	0.0258
41	0.0255	0.0258	0.0254
46	0.0253	0.0255	0.0251
56	0.0241	0.0243	0.0239
86	0.0242	0.0242	0.0240
126	0.0255	0.0256	0.0253
136	0.0241	0.0244	0.0240
141	0.0251	0.0252	0.0249
171	0.0242	0.0245	0.0249
176	0.0252	0.0253	0.0250

Table 3. The value of coefficients between main signal and denoised signals with selected functions

Wavelet function	Test 1	Test 2	Test 3
11	0.9487	0.9508	0.9501
21	0.9479	0.9486	0.9490
41	0.9499	0.9501	0.9508
46	0.9510	0.9515	0.9519
56	0.9556	0.9559	0.9564
86	0.9551	0.9564	0.9563
126	0.9498	0.9510	0.9509
136	0.9553	0.9555	0.9560
141	0.9516	0.9528	0.9526
171	0.9520	0.9520	0.9528
176	0.9515	0.9522	0.9521



(a)



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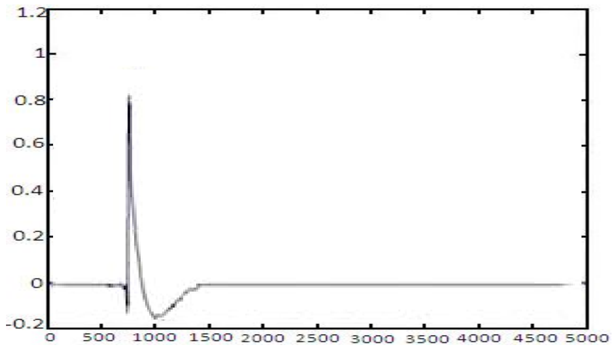
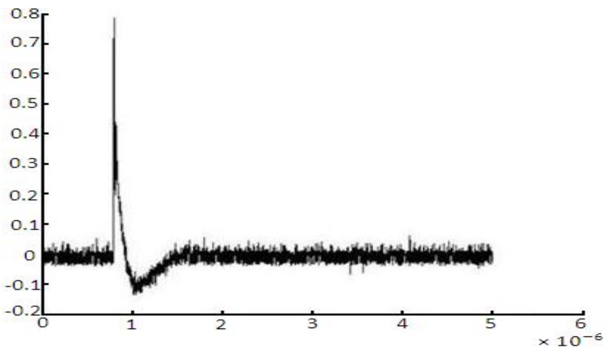
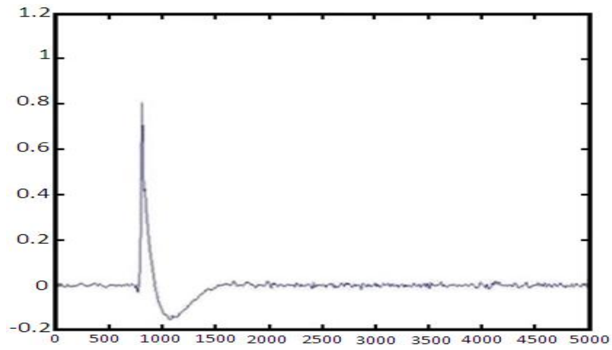


(c)

Figure 6. Surface discharge signals
(a) Origin signal
(b) Denoised
(c) Varied signal



(a)



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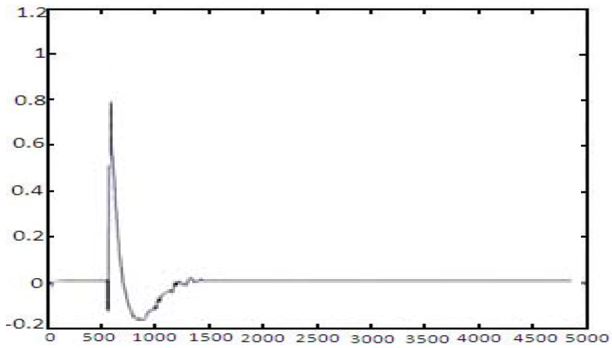

(c)

Figure 7. Cavity discharge
(a) Origin signal
(b) Denoised
(c) Varied signal

IV. ABOUT STUDIED FEATURES AND NUMERICAL RESULTS OF FEATURES

The five features, which are determining the properties of different partial discharge signals, will be presented in this part. These features depend due to their intrinsic characteristics are meaningful in adjustment comparison in the same conditions. In different conditions the value of these features will be changed. The features are mentioned below.

1- The peak value of signal
2- The mean (average value of signal)
3- The effective value of signal is

$$RMS = \sqrt{[\sum_{i=1}^{n} X_i^2]/n} \quad (1)$$

where X_i is present value of signal and n is length of signal.

4- The standard division of signal is

$$\sigma = \sqrt{[\sum_{i=1}^{i=n} (X_i - X_{mean})^2]/n} \quad (2)$$

where X_i and X_{mean} are present value and mean value of signal by sequence, and n is length of signal.

5- The dispersal factor of signal is

$$CV = \sigma / X_{mean} \quad (3)$$

where X_{mean} is mean value of signal by sequence, and σ is standard division of signal. The values could be calculated for each strategy and each test condition and will be obtained for origin signal, denoised signal and varied signal.

In Tables 4 till 10 the results have been presented for 3 tests of 10 applied tests, in one of the above mentioned conditions. The results for being useful must be per united. So the tables show per unit values of features also. It is clear that in some tests, where the noisy signal has been studied, the results are more acceptable than others. In some else, the denoised signals give better results, and in some others the varied signals deliver better results. For example in studying average value of signal, the first strategy is not quite and second strategy isn't either. But third strategy has remarkable power of distinguishing. However the first strategy has acceptable results in calculating effective value. Thus for achieving admissible results, depends to studied feature, we decide to not denoise signal or denoise it or even applying some changes on the signal. Similarly, the importance of these characteristics in different situations and for different type of coronas can be considered.

V. CONCLUSIONS

In this paper, 3 types of PD, corona discharges, surface discharges and cavity discharges have been studied, which are the most occurred in transformers. These three PD signals, are different in some attributes, although there are similar in some else's. So we focused on the differences to classify them. To classify them by the properties, some distinguishing features as like as peak value of signal, mean (average) value of signal, effective value of signal, standard division of signal and dispersal factor of signal have been studied. These features are useful in comparison. Each type of PD was tested 10 times for three different conditions and signals, which might have noises, were recorded. Then three distinct strategies were raised up to classify PD types. By applying strategies, and using features, differences of signals have been cleared, and classification was done. Also it was cleared that for different features, different strategies are useable. To attain honorable numerical results, some results were per united. The results were listed in Tables 2 till 6.

Table 4. Voltage peak values for Corona, Surface and Cavity discharge in 3 different tests

Voltage Peak		Corona Discharge	Surface Discharge	Cavity Discharge
Strategy 1	Test 1	1.2707	1.1325	1.1544
	Test 2	1.2676	1.1064	1.1752
	Test 3	1.2842	1.1012	1.1658
	Average	1.275	1.113	1.165
	Per Unit	1	0.87	0.92
Strategy 2	Test 1	0.7347	0.9277	0.9695
	Test 2	0.7132	0.9192	0.9714
	Test 3	0.7447	0.9145	0.9878
	Average	0.7300	0.9200	0.9670
	Per Unit	1	1.26	1.35
Strategy 3	Test 1	0.7347	0.9277	0.9695
	Test 2	0.7132	0.9192	0.9714
	Test 3	0.7447	0.9145	0.9878
	Average	0.7302	0.9205	0.9672
	Per Unit	1	1.26	1.34

Table 5. Average values for Corona, Surface and Cavity discharge in 3 different tests

Average Value		Corona Discharge	Surface Discharge	Cavity Discharge
Strategy 1	Test 1	-0.0064	-0.0053	-0.0062
	Test 2	-0.0061	-0.0061	-0.0060
	Test 3	-0.0057	-0.0060	-0.0056
	Average	-0.0060	-0.0057	-0.0058
	Per Unit	1	0.94	0.97
Strategy 2	Test 1	-0.0064	-0.0053	-0.0062
	Test 2	-0.0061	-0.0061	-0.0060
	Test 3	-0.0057	-0.0060	-0.0056
	Average	-0.0061	-0.0058	-0.0060
	Per Unit	1	0.95	0.97
Strategy 3	Test 1	-0.0025	-0.0022	-0.0021
	Test 2	-0.0026	-0.0023	-0.0022
	Test 3	-0.0025	-0.0024	-0.0022
	Average	-0.0025	-0.0023	-0.0022
	Per Unit	1	0.92	0.88

Table 6. Effective values for Corona, Surface and Cavity discharge in 3 different tests

Effective Value		Corona Discharge	Surface Discharge	Cavity Discharge
Strategy 1	Test 1	0.0819	0.0713	0.0740
	Test 2	0.0830	0.0712	0.0736
	Test 3	0.0821	0.0712	0.0738
	Average	0.0824	0.0713	0.0740
	Per Unit	1	0.86	0.9
Strategy 2	Test 1	0.0750	0.0701	0.0714
	Test 2	0.0761	0.0693	0.0710
	Test 3	0.0754	0.0694	0.0711
	Average	0.0751	0.0696	0.0712
	Per Unit	1	0.93	0.95
Strategy 3	Test 1	0.0746	0.0698	0.070۹
	Test 2	0.0745	0.0690	0.0705
	Test 3	0.0750	0.0691	0.0706
	Average	0.0757	0.0693	0.0706
	Per Unit	1	0.091	0.093

Table 7. Standard division values for Corona, Surface and Cavity discharge in 3 different tests

Standard Division		Corona Discharge	Surface Discharge	Cavity Discharge
Strategy 1	Test 1	0.0816	0.0721	0.0735
	Test 2	0.0828	0.0714	0.0731
	Test 3	0.0819	0.0713	0.0733
	Average	0.0821	0.0716	0.0733
	Per Unit	1	0.87	0.89
Strategy 2	Test 1	0.0748	0.0679	0.0711
	Test 2	0.0758	0.0671	0.0708
	Test 3	0.075۲	0.0671	0.0708
	Average	0.0753	0.0674	0.0710
	Per Unit	1	0.89	0.94
Strategy 3	Test 1	0.0746	0.0678	0.0705
	Test 2	0.0745	0.0669	0.0705
	Test 3	0.0750	0.0670	0.0705
	Average	0.0747	0.0671	0.0705
	Per Unit	1	0.89	0.94

Table 8. Standard division values for Corona, Surface and Cavity discharge in 3 different tests

Dispersal Factor		Corona Discharge	Surface Discharge	Cavity Discharge
Strategy 1	Test 1	-12.8123	-13.4980	-11.7984
	Test 2	-13.6327	-11.7639	-12.2769
	Test 3	-14.3965	-12.8435	-13.0669
	Average	-13.6138	-12.9467	-12.3807
	Per Unit	1	0.95	0.9
Strategy 2	Test 1	-13.7292	-12.1184	-11.3835
	Test 2	-13.5068	-12.3832	-11.2603
	Test 3	-13.1974	-12.5664	-11.6160
	Average	-13.5	-12.3	-11.2
	Per Unit	1	0.9	0.82
Strategy 3	Test 1	-29.2787	-26.1069	-22.4172
	Test 2	-28.9118	-26.5514	-218060
	Test 3	-30.4979	-26.8420	-22.5264
	Average	-29.7	-26.50	-22.2
	Per Unit	1	0.9	0.75

REFERENCES

[1] H. Golahmadi, Y. Nakhaei, “Choosing the Best Wavelet Function for Denoising the Partial Discharge Signal Occurred at Surface Discharge Phenomena”, 8th International Conference on Technical and Physical Problems of Power Engineering (ICTPE-2012), No. 73, Code 05HVE02, pp. 351-355, Fredrikstad, Norway, 5-7 September 2012.

[2] A. Akbari, H.R. Mirzaei, M. Kharezi, A. Mazhab Jafari, “New Informative Features of Partial Discharges and Limitations of Conventional Measuring Devices”, XVth International Symposium on High Voltage Engineering University of Ljubljana, Ljubljana, Slovenia, 27-31 August 2007.

[3] IEC 60270, “High Voltage Test Techniques Partial Discharge Measurements”, Ed. 2000.

[4] H. Golahmadi, B. Tousi, “Denoising Partial Discharge”, 24th International Power System Conference, Iran, Tehran, 2009.

[5] N.C. Sahoo, M.A. Salama, “Trends in Partial Discharge Pattern Classification”, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 12, No. 2, April 2005.

[6] A. Mazhab Jafari, A. Akbari, M. Kharezi, “Partial Discharge Localization in Transformers Using Detailed Modeling of Winding and Calibration Pulses”, IEEE International Conference on Solid Dielectrics, pp.536-539, Winchester, UK, 2007.

BIOGRAPHIES

Hamid Golahmadi was born in Khoy, Iran in 1985. He received his B.Sc. degree in Electrical Engineering in August 2008 from K.N. Toosi University of Technology, Tehran, Iran, and M.Sc. degree in Power Engineering in December 2010 from Urmia University, Urmia, Iran. Since January 2012, he has been studding Ph.D. in Power Engineering in JDEVS, Tehran, Iran. Since January 2011 he is a lecturer and researcher at Urmia University. His research interests are in advanced power electronic and FACTS, partial discharge classification and localization in power transformers, fault location and HVDC transmission system.

Murtaza Farsadi was born in Khoy, Iran in September 1957. He received his B.Sc. degree in Electrical Engineering, M.Sc. degree in Electrical and Electronics Engineering and Ph.D. degree in Electrical Engineering (High Voltage) from Middle East Technical University (METU), Ankara, Turkey in 1982, 1984 and 1989, respectively. He is now an Assistant Professor in Electrical Engineering Department of Urmia University, Urmia, Iran. His main research interests are in high voltage engineering, industrial power system studies and FACTS, HVDC transmission systems and DC/AC active power filters, power quality and renewable energies.