Classification of Partial Discharge Using Combination of Acoustic Emission Detection and S-Transform Analysis

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Abstract— **Partial Discharge (PD) is an electrical phenomenon which causes insulation to deteriorate and frequently is the reason for breakdown of an insulation system resulting in failure of the equipment. This project is conducted in order to identify a detected partial discharged using non-contact type of acoustic measurement. This study will be performed with laboratory experimental work in order to validate the experimental data. With the aid of an ultrasonic probe as detecting device, the ultrasonic signal is recorded and the data will be analysed in personal computer (PC) with the aid of MATLAB software. The recorded time-domain signal is then transformed into frequency-domain by using the S-Transform (ST) analysis. This study is to detect the acoustic PD and classify the pattern of ultrasonic sound emitted.**

Keywords: Partial Discharge(PD), S-Transform, acoustic emission.

I. INTRODUCTION

Partial Discharge (PD) phenomenon is one of the major factors that may lead to insulation deterioration in power transformers. Partial discharge occurs in gaseous, liquid, solid or in any combination of insulation system at extremely non uniform field locations above particular field intensity. In this study, the term partial discharge refers to a discharge that does not completely bridge the space between the electrodes. The discharge may be in a gas filled void inside an insulating material, or around an electrode in a gas [1]. But partial discharges are considered to be the major reason for aging and eventual failure of electrical insulation, so measurements of partial discharge activity are an item in the test program for most types of high voltage /radio frequency equipment [2].

Several techniques were developed to detect partial discharge activity. Acoustic detection has been utilized for PD signal detection in power transformers. Acoustic detection has several advantages compared to other techniques such as: it is immune to electromagnetic interference and it can be used to locate the PD activity [3-7].

The objective of this study is to classify the different type of partial discharge from the pattern of the ultrasonic sound emitted. The S-Transform (ST) will be used to analyse data from the experimental ultrasonic in laboratory. ST is employed to obtain the time-frequency representation of original PD pulses.

II. S-TRANSFORM (ST)

The ST originally proposed by the geophysicist Stockwell [8], is a time-frequency representation known for its local spectral phase properties. A key feature of the ST is that it uniquely combines a frequency dependent resolution of the time-frequency space with absolutely referenced local phase information. This allows one to define the meaning of phase in a local spectrum setting, and results in many advantageous characteristics. It also exhibits a frequency invariant amplitude response, in contrast to the wavelet transform.

ST can be expressed as an operation of the Fourier spectrum $X(f)$ of $x(t)$:

$$S_x(t,f) = \int_{-\infty}^{\infty} x(\tau)\,|f|\, e^{-\pi(t-\tau)^2 f^2} e^{-j2\pi f\tau} d\tau \qquad (1)$$

Illustrations of the properties of the ST approach are given and a comparison to wavelet transform is performed. The ST is shown to have absolutely referenced phase information, a quality that the continuous wavelet transform is lacking. In addition, the ST is shown to have a frequency invariant amplitude response in contrast to the continuous wavelet transform which attenuates high frequency signals relative to the low frequency signals [9].

III. Methodology

In this study, an ultrasonic detector is used to measure the acoustic PD signals. This device capable of recording and store the ultrasonic sound detected. The 40 kHz of frequency of the ultrasonic device has been used and it is the best detection frequency which is also adopted in this work. The acoustic signal detected from the ultrasonic device varies from 16 dB to 18 dB. The ultrasonic probe is placed 0.6m in front of the test object because the better signal will be obtained and also for safety. The flow chart in Figure 1 shows the illustration of methodology during experiment works.

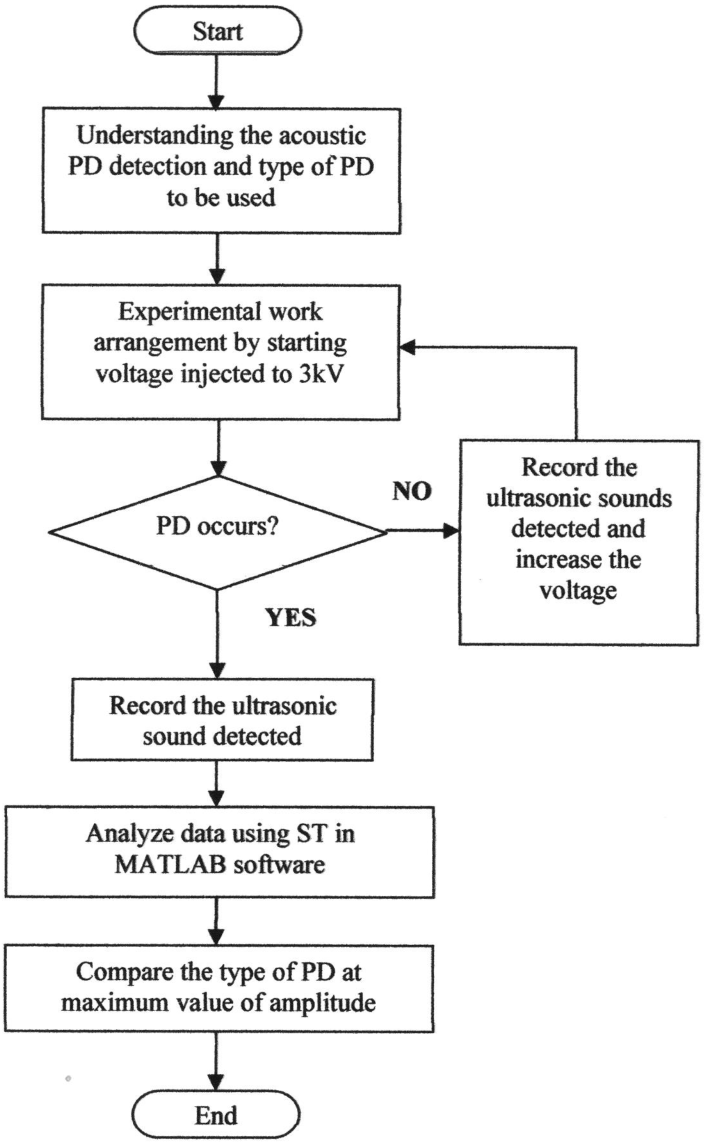

Figure 1. Flow chart of methodology.

A. *Experimental work*

The experimental works begin with the arrangement and the setup of the apparatus in order to produce the partial discharge. There are step procedures of the experimental in gathering the PD data. Firstly, a device called 'Hipotronics AC Dielectric Test' at operation frequency of 50 Hz supply high voltage to device under test (DUT) using high voltage cable. After that, the acoustic signal of the PD source will be measured using the ultrasonic device placed 60cm from the PD source. The measured data will be converted into waveform graph. Next, the converted PD waveform graph will be plotted using ST in MATLAB software. Finally, from the plotted waveform, compare the pattern of graph obtained from the tabulated results to define the type of PD. The illustration of non-contact method is shown in Figure 2.

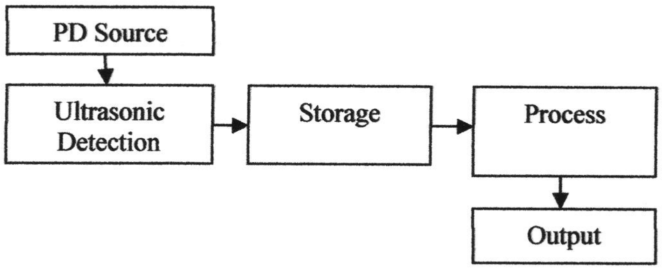

Figure 2. Block diagram of the non-contact method.

B. *Partial discharge types*

The following subsection shows the types of PD produced in the experimental works.

1) *Internal Discharge*

A set of test vessel with capabilities to withstand high voltage in order to produce the internal discharge was used as shown in Figure 3. The vessel must be in air tight condition. The perspex has been used in order to avoid the corona discharge and it's placed in the middle of the electrode (brass plate).

While for the internal discharge experiment, the test vessel also is injected 3kV at the starting. During this time, there are no PD occurs. After increasing the voltage to 7kV, the internal discharge occurred and the acoustic sound emitted is recorded for 10 seconds. The acoustic sound emitted at internal discharge is lower than surface discharge. The complete breakdown occurs after the voltage increased at 7.8kV.

Figure 3. Set of test vessel for produce internal discharge.

2) *Surface Discharge*

Two brass plates have been used as the electrode for the surface discharge as shown in Figure 4. Similar to internal discharge, the perspex is used as insulation material that is placed in the middle of the electrode (brass plate). The top electrode is injected with high voltage and the bottom electrode is connected to ground.

For surface discharge experiment, the test object is injected 3kV voltage at the starting. At this time, there are no PD occurs by using ultra probe detector. After the voltage increased at 6kV, the surface discharge occurred and the acoustic sound emitted is recorded for 10 seconds before complete breakdown happened.

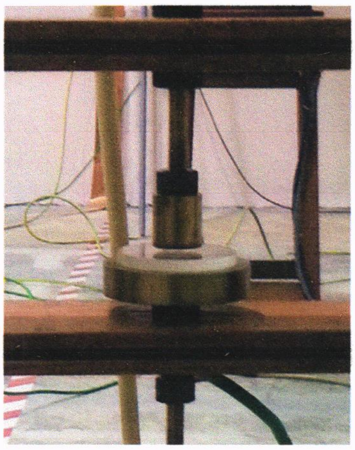

Figure 4. The apparatus arrangement for the surface discharge.

IV. Result and Discussion

All measured data is converted into waveform graph. The converted PD waveform graph will be plotted using ST in MATLAB software. The results obtained from the matrix computation are plotted as shown in figures below.

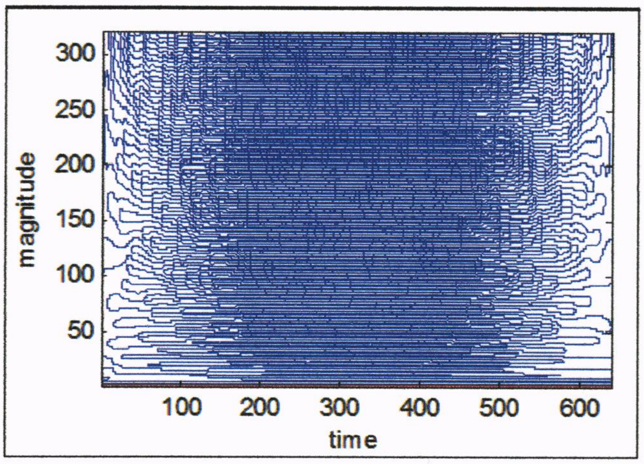

Figure 5. The Contour when no PD occurs.

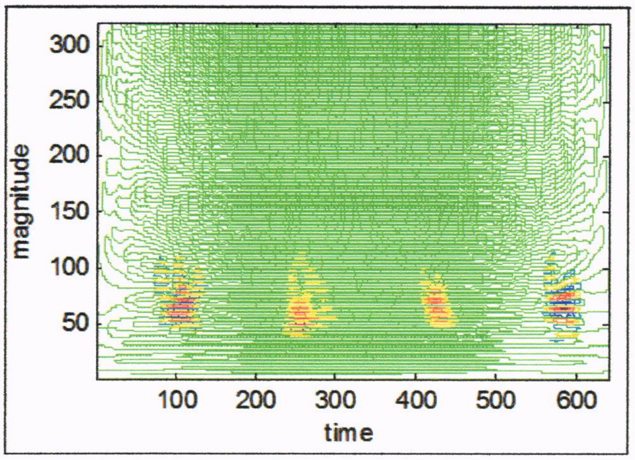

Figure 6. The Contour when PD occurs at surface discharge.

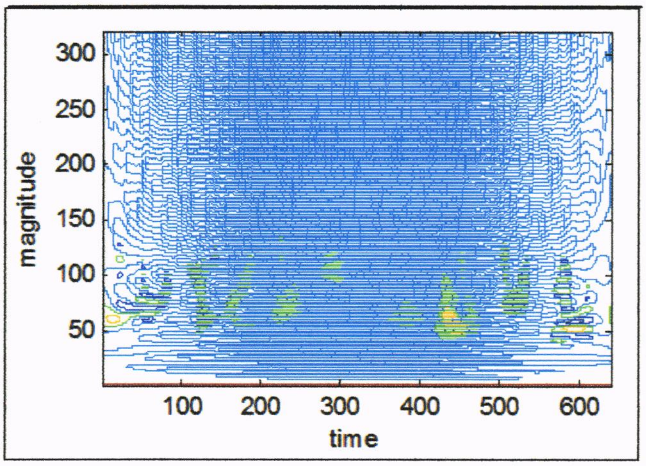

Figure 7. The Contour when PD occurs at internal discharge.

Figure 5, 6, and 7 show the different contour of each partial discharge types. The contour when non PD occurs is normal and there is no different colour. While the surface discharge and the internal discharges have their own characteristic of the contour. The surface discharge contour show the PD occurs is obvious for the certain part than the contour at internal discharge is scattered.

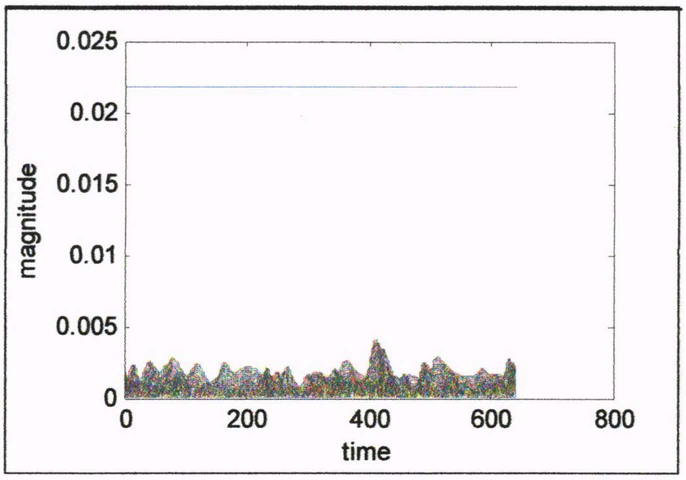

Figure 8. The inverse matrix graph when no PD occurs.

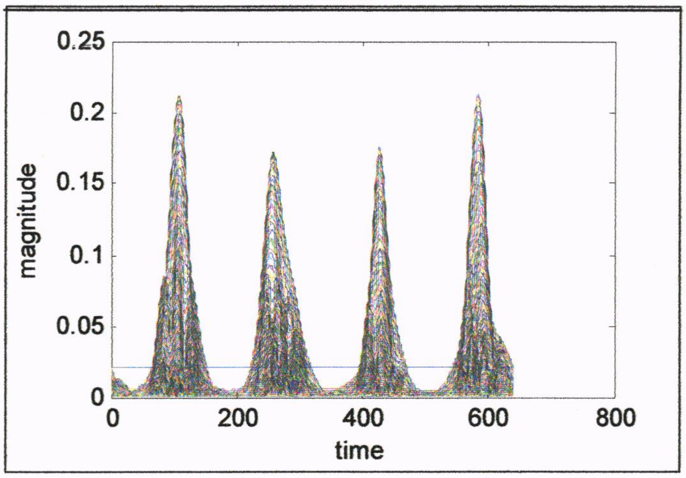

Figure 9. The inverse matrix graph when PD occurs at surface discharge.

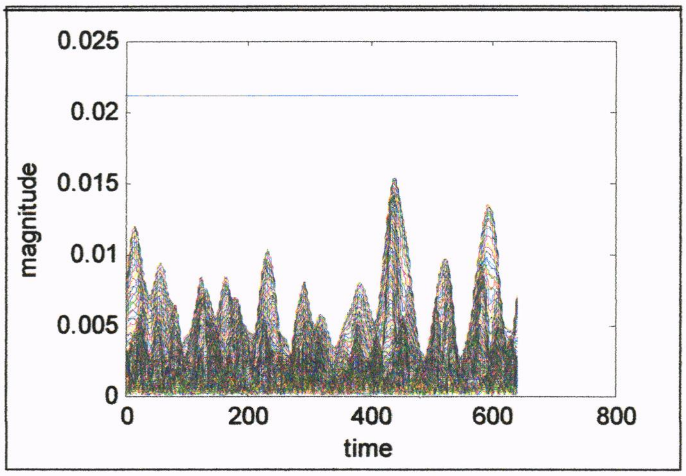

Figure 10. The inverse matrix graph when PD occurs at internal discharge.

Figure 8, 9, and 10 shows the graph plotted from the inverse matrix of ST analysis. The pattern from graph is different. When no PD occurs, the magnitude of discharge is below than the PD occurs at internal discharge. While the magnitude of discharge at surface is obvious sharpness for certain part than internal discharge. All of this graph will be clearer by converted the s transform matrix computation into sum absolute as shown in figure below.

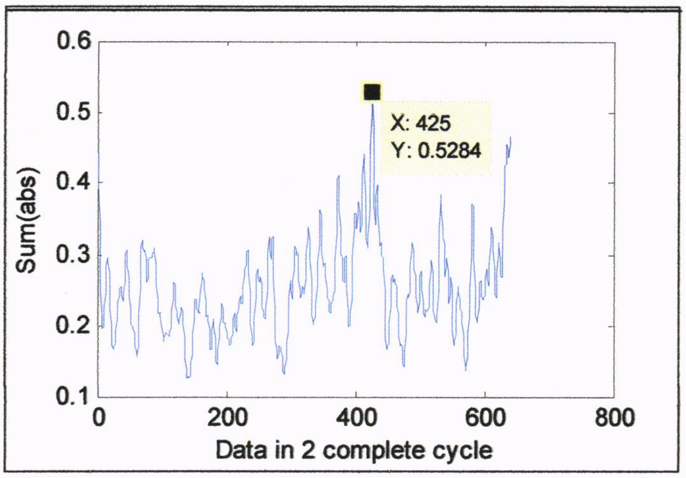

Figure 11. The Sum Absolute graph when no PD occurs.

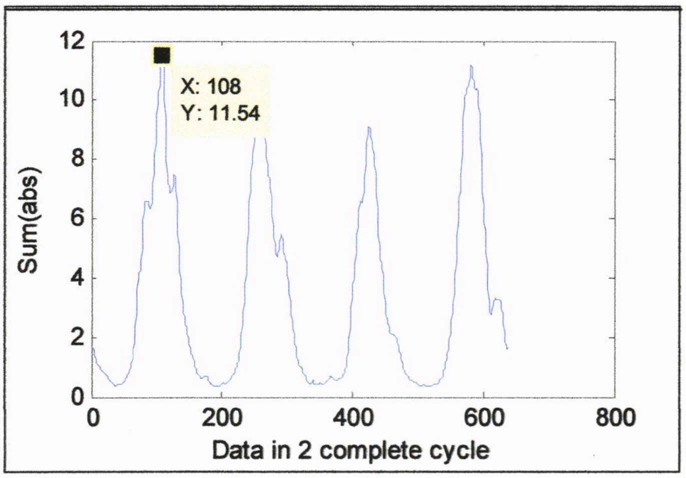

Figure 12. The Sum Absolute graph when PD occurs at surface discharge.

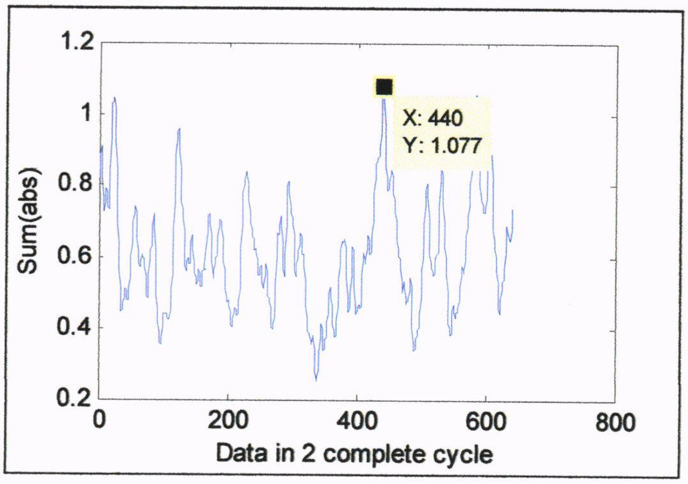

Figure 13. The Sum Absolute graph when PD occurs at internal discharge.

Figure 11, 12, and 13 shows the sum absolute graph from computation matrix of ST analysis. When no PD occurs, the maximum value of sum absolute is 0.5284. For surface discharge, the maximum value is 11.54. While for internal discharge, the maximum value is 1.077. The maximum value sum absolute for surface discharge is greater than internal discharge while the maximum value sum absolute for internal discharge is greater than non PD occurs.

TABLE 1 MAXIMUM DATA IN EACH 2 COMPLETE CYCLE.

Type of PD	Maximum Data Sum Absolute in Each 2 Complete Cycle				
	Data 1	*Data 2*	*Data 3*	*Data 4*	*Data 5*
Non-PD	0.5284	0.4343	0.4535	0.4802	0.4774
Surface	11.5400	14.1000	13.1800	17.6400	11.1600
Internal	1.0770	1.0880	1.7130	1.4250	1.5530

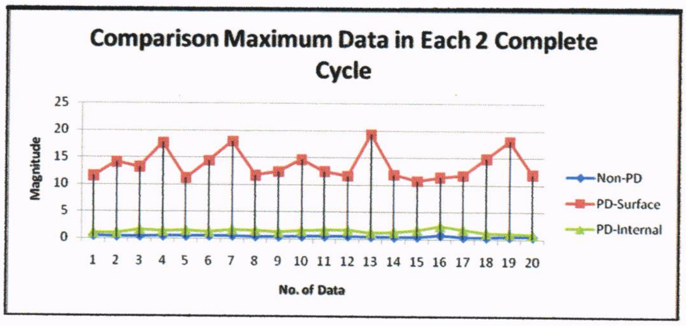

Figure 14. The comparison maximum data in each 2 complete cycle.

Table 1 and Figure 14 shows the comparison maximum data in each 2 complete cycle. 20 data in each 2 complete cycle sum absolute have been plotted in graph. The graph shows the highest maximum amplitude is known as PD surface. The middle maximum amplitude is known as PD internal while the lowest maximum amplitude is known as Non PD. From tabulated results, it shows the different pattern of plotting graph and the different values of each type of partial discharges.

CONCLUSION

This study is to classification the different type of partial discharge (PD) from the pattern of the ultrasonic sound emitted. The result obtained by using ST is presented. It can be concluded the advantages of using ST is employed to obtain the time-frequency matrix of the registered PD pulses, to extract more information and eliminate the influence of pulse polarity. The ST amplitude matrix is used to compute the similarities between various pulses. The types of PD have been classified by comparing the maximum amplitude data and the pattern of the contour obtained.

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REFERENCES

[1] James J, "Partial Discharge in High Voltage Equipments-HV Cable", Properties and Applications of Dielectric Materials, 2009. ICPADM 2009. IEEE 9th International Conference, July 2009.

[2] Rahman, M.K.A, "Classification Of Partial Discharge Transient Patterns Using Texture Analysis Algorithms", Electrical Insulating Materials, 1998. Proceedings of 1998 International Symposium, Sept. 1998.

[3] Y Tian, P L Lewin, A E Davies, Z Richardson, "Acoustic Emission Detection Of Partial Discharges In Polymeric Insulation", High Voltage Engineering, 1999. Eleventh International Symposium on (Conf. Publ. No. 467), 1999.

[4] A. Swedan, A.H. El-Hag, K. Assaleh, "Enhancement of Acoustic Based Partial Discharge Detection Using Pattern Recognition Techniques", Electric Power and Energy Conversion Systems (EPECS), 2011 2nd International Conference, Nov. 2011.

[5] S. Birlasekaran, "Identification of the type of partial discharges in an operating 16kV/250 MVA generator", Electrical Insulation and Dielectric Phenomena, 2003. Annual Report. Conference, Oct. 2003.

[6] D Zhu, A J McGrail, S Swingler, D W Auckland, B R Varlow, "Partial Discharge Detection in Cable Termination Using Acoustic Emission Techniques and Adaptive Signal Processing", Electrical Insulation, 1994, Conference Record of the 1994 IEEE International Symposium, Jun 1994.

[7] Wei Jiang, Fan Liu, Zhiyuan Wang, "Transformer Partial Discharge Detection Using Electrical-Ultrasonic Technology", Power and Energy Engineering Conference (APPEEC), 2012 Asia-Pacific, March 2012.

[8] Ke Wang,Ruijin Liao, Lijun Yang, Shaorong Li, Chaoliang Qi, "Multiple PD Sources Separation of Oil-Paper Insulation Using S Transform based Similarity", High Voltage Engineering and Application (ICHVE), 2012 International Conference, Sept. 2012.

[9] Gaolin Wu, Ruilin Xu, Ke Wang, Qian Wang, Yan Yang, Xian Meng, " PD Pattern Recognition Using S Transform and Two-directional Two-dimensional Principal Component Analysis", High Voltage Engineering and Application (ICHVE), 2012 International Conference, Sept. 2012.