

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	iv
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF SYMBOLS AND ABBREVIATIONS	xvi
1	INTRODUCTION	1
	1.1 ELECTRICAL POWER QUALITY - AN OVERVIEW	1
	1.2 IMPORTANCE OF PQ	3
	1.2.1 Utility Perspective	3
	1.2.2 Equipment Manufacturer's Perspective	4
	1.2.3 Consumer's Perspective	4
	1.3 PQ DISTURBANCES	4
	1.4 PQ MONITORING	9
	1.4.1 Traditional Methods of PQ Monitoring	9
	1.4.2 Present Method of PQ Monitoring	9
	1.5 PQ STANDARDS	10
	1.5.1 IEC 61000 Series of Standards	11
	1.5.2 IEEE 1195 Standards	11
	1.6 IMPORTANCE OF THE RESEARCH	12
	1.7 LITERATURE SURVEY	12
	1.8 RESEARCH GAP IDENTIFIED	18
	1.9 OBJECTIVES	20
	1.10 OUTLINE OF THE THESIS	20
	1.11 CONCLUSION	21

2	WAVELET BASED FEATURE EXTRACTION	23
2.1	INTRODUCTION	23
2.1.1	Representation of Signals through Transforms	24
2.1.2	Representation of Signals through Wavelet Transforms	25
2.1.3	Mother Wavelet, Wavelet Family and Wavelet Domain	27
2.1.4	Filtering Process	27
2.1.5	Wavelet Reconstruction	28
2.2	MULTI-RESOLUTION ANALYSIS	29
2.3	FEATURE EXTRACTION	30
2.4	SELECTION OF WAVELETS AND DECOMPOSITION SCALE	34
2.5	CONCLUSION	40
3	COMPUTATIONAL ANALYSES OF PQ DATA USING NEURAL NETWORKS	41
3.1	INTRODUCTION	41
3.1.1	Artificial Neural networks	42
3.1.2	Neural Network Architectures	43
3.2	NEURAL NETWORK LEARNING	45
3.2.1	Hebbian Learning	45
3.2.2	Back Propagation Learning	45
3.2.3	Training and Testing Neural Networks	46
3.2.4	Choosing the Number of Neurons	47
3.2.5	Choosing the Initial Weights	47
3.2.6	Choosing the Learning Rate	47
3.3	NEURAL NETWORKS FOR THE ANALYSIS	48

3.3.1	Feed Forward Multilayer Layer Neural Network	48
3.3.2	Generalized Regression Neural Network	49
3.3.3	Learning Vector Quantization Neural Network	51
3.3.4	Probabilistic Neural Network	52
3.3.5	Radial Basis Function Neural Network	54
3.4	CASE STUDY	55
3.4.1	Data Generation	55
3.4.2	Matlab Coding to Generate Pure Sine Wave	55
3.4.3	Matlab Coding to Generate Voltage Sag	56
3.4.4	Data Extraction	57
3.4.5	Various Layers Computation and Network Training	62
	3.4.5.1 Input Layer Computation	62
	3.4.5.2 Hidden Layer computation	63
	3.4.5.3 Output Layer Computation	63
3.5	RESULT AND DISCUSSION BASED ON FEATURES	74
3.6	DETECTION AND CLASSIFICATION PERFORMANCE UNDER NOISY CONDITION	77
3.7	CONCLUSION	79
4	DETECTION AND CLASSIFICATION USING FUZZY SYSTEMS	80
4.1	INTRODUCTION	80
4.1.1	Fuzzy Sets	82
4.1.2	Membership Functions	82
	4.1.2.1 Gaussian Membership Function	83
	4.1.2.2 Trapezoidal Membership Function	84

4.1.2.3	Sigmoidal Membership Function	85
4.1.2.4	Generalized Bell Membership Function	86
4.2	FUZZY SYSTEMS	86
4.2.1	Mamdani Fuzzy Logic	87
4.2.2	Defuzzification Methods	88
4.3	RESULT AND DISCUSSION USING FUZZY LOGIC	89
4.3.1	Detection and Classification using wavelet decomposition Levels	96
4.3.2	Comparison of Proposed Work with Real Time Data	100
4.4	PARTICLE SWARM OPTIMIZATION FOR RANGE ESTIMATION FOR MEMBERSHIP FUNCTION	101
4.4.1	Detection and Classification Using FL - PSO	103
4.4.2	Result and Discussion Based on Features	104
4.4.3	Performance under Noisy Condition	106
4.5	CONCLUSION	107
5	CONCLUSION AND FUTURE SCOPE	108
5.1	CONCLUSION	108
5.2	FUTURE SCOPE	111
	REFERENCES	113
	LIST OF PUBLICATIONS	120

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1.1	Categories and characteristics of PQ disturbances	8
2.1	Results of selection of wavelet function	35
2.2	Results of selection of scale	36
3.1	Data for training	62
3.2	Training and validation	64
3.3	Classification result of FFML	69
3.4	Classification result of LVQ	70
3.5	Classification result of GRNN	71
3.6	Classification result of PNN	72
3.7	Classification result of RBFNN	73
3.8	Comparison of proposed RBFNN on number of features for various networks	75
3.9	Comparison of proposed RBFNN on number of features with other works	76
3.10	Simulation result of classifying the power quality problems with noise	78
4.1	Comparison of proposed fuzzy logic with Other works practical data	101
4.2	Comparison of classification rate of FL-PSO	103
4.3	Comparison of proposed fuzzy logic on number of features	104
4.4	Comparison of proposed fuzzy logic on number of features with other works	105
4.5	Performance comparison	106
5.1	Overall performance comparison	110

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1.1	Normal voltage sag	5
1.2	Normal voltage swell	5
1.3	Normal voltage interruption	6
1.4	Normal voltage fluctuation	6
1.5	Normal voltage Harmonics	7
2.1	Wavelet	25
2.2	Examples of wavelets	26
2.3	Mother wavelet and wavelet family	27
2.4	(a) Multi-resolution analysis decomposition and (b) reconstruction	29
2.5	(a) Normal Signal (b) Pure sag (c) Pure swell (d) Momentary interruption (e) Voltage fluctuation (f) Harmonics (g) Transients (h) Sag with harmonics (i) Swell with harmonics (j) Momentary interruption with harmonics	32
2.6	(a) Voltage fluctuation with harmonics (b) Sag with fluctuation (c) Swell with fluctuation (d) Sag with momentary interruption (e) Swell with momentary interruption (f) Sag with swell and momentary interruption (g) Sag with swell and harmonics (h) Harmonics with fluctuation and interruption (i) Sag with fluctuation, momentary interruption and Swell (j) Sag with fluctuation, momentary interruption, swell and harmonics	33

2.7	Voltage sag approximate coefficient level	36
2.8	Voltage sag first decomposed level (d1)	37
2.9	Voltage sag third decomposed level (d3)	37
2.10	Voltage sag fifth decomposed level (d5)	37
2.11	Voltage interruption approximate coefficient level	38
2.12	Voltage interruption first decomposed level (d1)	38
2.13	Voltage interruption third decomposed level (d3)	38
2.14	Voltage interruption fifth decomposed level (d5)	39
3.1	Artificial neural networks	43
3.2	FFML architecture	48
3.3	GRNN architecture	50
3.4	LVQ architecture	51
3.5	PNN architecture	53
3.6	RBFNN architecture	54
3.7	Normal Signal	56
3.8	Voltage sag	57
3.9	Wave menu	58
3.10	Wavelet 1-D analyses	59
3.11	Approximate and detail coefficient of the sag	59
3.12	Extracted features	60
3.13	FFT spectrums for the sag	60
3.14	Sag at various decomposition levels.	61
3.15	Standard Deviation - Sag disturbance compared with pure sine waveform	61
3.16	Neural network data manager	65
3.17	Networks specifications	66
3.18	Neural networks architecture	66
3.19	Training input and target specification	66

3.20	Training specification	67
3.21	Performance status	67
3.22	The training, testing and validation plot for a sag	68
3.23	NN Comparison	74
4.1	Gaussian membership function	84
4.2	Trapezoidal membership function	84
4.3	Sigmoidal membership function	85
4.4	(a) Generalized bell membership Function	86
4.5	Normal signal, (b) Pure sag, (c) Pure swell, (d) Momentary interruption, (e) Transients	90
4.6	Features obtained for sag in voltage signal	91
4.7	Features obtained for swell in voltage signal	91
4.8	Fuzzy Expert System	92
4.9	Membership Function for amplitude	93
4.10	Membership Function for slope	93
4.11	Membership Function for energy	94
4.12	Membership Function for output	94
4.13	Fuzzy rules in rule editor	95
4.14	Implemented fuzzy rules for a sample data	96
4.15	(a) Outages (b) Harmonics distortion	96
4.16	Fuzzy expert system with wavelet decomposition levels	97
4.17	Decomposed PQ disturbance signals of outage	98
4.18	Decomposed PQ disturbance signals of harmonics	98
4.19	Membership function of wavelet decomposition levels	99
4.20	Membership function wavelet of various energy levels	99