Contents

	Acknow	ledgements	IV
	Abstract		V
	List of F	igures	X
	List of T	ables	X
1.	Introduction		
	1.0.	Background	1
	1.1.	Power quality and power system events	1
	1.2.	Power quality monitoring objectives	4
	1.3.	Motivation of the work	6
	1.4.	Outline of the thesis	7

2. Frequency Measurement

2.0	Introduction	13
2.1	Applications of Frequency Measurement	15
2.2	Various Frequency Tracking Methods	16
2.2.1	Zero Crossing Methods	16
2.2.2	Quadratic Form	16
2.2.3	Discrete Fourier Transform with Phase Compensation	17
2.2.4	Demodulation	17
2.2.5	Decomposition of Single Phase Into Orthogonal	18
2.2.6	Non-Linear Least Squares Estimation	. 18
2.2.7	Linear Estimation of Phase (LEP)	19

iii

Digital Filters	20
Block diagram of the proposed System	22
Mathematical Analysis	36
Extension to Three-Phase System	39
Simulation Results	41
Simulation on Excel	41
Simulation on Matlab [™]	45
Methodology for Frequency Measurement	56
Hardware and Software	57
Flowchart	60
Results	61
Conclusions	62
	Block diagram of the proposed System Mathematical Analysis Extension to Three-Phase System Simulation Results Simulation on Excel Simulation on Matlab [™] Methodology for Frequency Measurement Hardware and Software Flowchart Results

3. Four Quadrant Power Measurement

	3.0	Introduction	63
	3.1	Active and Reactive Power Measurement	66
	3.2	Measurement Of Active and Reactive Power For	
		Different cases	69
	3.3	Various Power Theories	77
	3.3.1	Power Components in Sinusoidal Conditions	77
	3.3.2	Fryze Theory	78 _.
	3.3.3	Kusters And Moore Theory	79
	3.3.4	Enslin And Van Wyk Theory	80
	3.3.5	Distortion Power	82
•	3.3.6	IEEE Power Definitions	83
	3.3.7	Time Domain Czarnecki Theory	84
	3.3.8	Akagi P-Q Theory	85

iv

.

	3.4	Three Phase Sinusoidal Voltage applied to Linear Load	88 .
	3.5	Three Phase Sinusoidal Voltage Supplying a Non-Linear Load	88
	3.6	Unbalanced Three-Phase 4-Wire System	90
	3.7	Principles of Four Quadrant Power Measurement	93
	3.8	Concept of Variable Power Tariffs	93
	3.9	Mathematical Analysis	95
	3.10	Simulation	97
	3.11	Block Diagram for Four Quadrant Power Measurement	119
	3.12	Hardware and Software	120
	3.13	Flowchart	122
	3.14	Results	123
	3.15	Conclusions	128
4.	On Line	Tracking of Harmonics in Power Systems	
	4.0	Introduction	130
	4.1	Applications of Harmonic Measurement	131
	4.2	Various Harmonic Measurement Methods	133
	4.2	1 Frequency domain method	134
	4.3	Wavelet Based Harmonic Estimation	136
	4.4	Kalman Filter	136
	4.5	Harmonic Estimation using Kalman Filter	143
	4.6	Simulation	152
	4.7	Hardware and Software	163
	4.8	Flowchart	165
	4.9	Results	166
	4.10	Conclusions	167

v

5. Flicker Measurement

5.0.	Introduction	169
5.1.	Various Methods for Flicker Measurement	171
5.1.1	. British Method	171
5.1.2	. French Method	172
5.1.3	. IEC 61000-4-15	173
5.2.	Modified Algorithm for Flicker Measurement	175
5.2.1. Measurement System Architecture		
5.3.	Simulation	181
5.4.	Experimental Setup and Actual Results	194
5.5.	Software	197
5.6.	Results	199
5.7.	Conclusions	200

6. DSP based techniques for processing of power quality parameters

6.0	Introduction	202
6.1	Application of DSP for PQ Measurement	203
6.1.1	Architecture of DSP	208
6.2	Proposed Multiprocessor system	214
6.2.1	Schematic of the Signal Conditioning module	216
6.2.2	Schematic of Multiprocessor System	219
6.2.3	Design of Multiprocessor System	223
6.2.4	Real time Digital Signal Acquisition	228
6.2.5	Design of PC Based Software	235
6.3	Software Development for Real Time Measurement	
	of PQ parameters	238

vi

6.4	Interfacing of Multiprocessor system with PC	240
6.5	Conclusions	241
7. Concl	usions	
7.0	General	242
7.1	Suggestions for future work	244
Paper	s Presented at National and International Conferences	245
References		
Annex	kure-I	253
Annex	kure-II	255

•

,

•