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Power quality data management and reporting methodologies

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Power Quality Data Management and Reporting Methodologies

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To my parents, wife Nimali,

and

son Tharindu

Declaration

Apart from the assistance stated in the acknowledgments and where reference is made in the text this thesis represents the original work of the author. The studies presented here have not been submitted for qualification at any other academic institution.

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Abstract

Deregulation of the Australian electricity supply industry is being accompanied by state regulator requirements for explicit statements on quality of supply backed up with field survey results. The continuous monitoring and storage of every voltage waveform at a selection of key sites will add significant expenses to the associated costs in managing the electricity industry while demanding an enormous quantity of information to be processed. This thesis gives a less comprehensive approach which may be accepted as a standard and consistent method of characterising the supply using simple set of power quality indices. Also presented is a power quality data management and reporting methodology which will give useful feedback to end-users, allowing assessment of operability of equipment as well as to the regulators and utilities, for the comparison of competitive distributor performance. This is supported by a power quality surveys of selected sites within electricity utilities in Australia.

The thesis gives a method of analysis that can be used to conveniently convert the collected raw data into useful knowledge, covering various types of power quality disturbances i.e. continuous or variation type and discrete or event type. Literature suggests that there has been many studies undertaken on continuous disturbance characterisation and related indices. Comprehensive standards have been developed specifying objectives to be met with standard limits for all continuous disturbance types. However, there are no generally acceptable methods for characterisation of discrete disturbances and limits are not well defined in international standards. A generalised method is proposed in this thesis to characterise discrete disturbances which is essentially based on a Disturbance Severity Indicator (DSI) proportional to the customer complaint rate. Scaled versions of the CBEMA and ITIC curves have been used to give an approximation to customer complaints.

The power quality reporting methodology suggested in this thesis is a consistent approach for power quality data analysis; categorised in to Short term, Medium term and Long term reporting, giving summary indices for each individual disturbance type and a single Unified Power Quality Index (UPQI) for each site and the utility. This approach would give an assessment of power quality rapidly, by means of representative numbers without overlooking important details. These indices, which are the result of characterisation and extraction from a large volume of power quality data, are easy to assess and representative of the actual impact of the disturbances they characterise. A novel methodology is also given to define discrete disturbance limits based on statistical information collected from large scale power quality surveys performed around the world.

Further, Multivariable Linear Regression (MVLR) has been used as a tool to identify hidden patterns and relationships within a large quantity of power quality data in an Australian monitoring campaign. For this, a factor analysis model has been developed using MVLR and complemented with Data Mining techniques; this model reveals the good and bad factors that influence utility power quality. Finally, the power quality data management guidelines and reporting methodologies developed have been applied to representative sites of several Australian utilities, to illustrate their ability to rank sites for power quality improvements and to rank utilities for power quality benchmarking.

Publications arising from the research work of this thesis

Herath, H.M.S.C., Gosbell, V.J., Perera, S., and Stirling, D. "Power Quality (PQ) Survey Factor Analysis using Multivariable Linear Regression (MVLR)," *IEEE International Conference of Harmonics and Quality of Power(ICHQP 2008),* Wollongong, NSW, Australia, Sept. 2008, Paper 1145.

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List of abbreviations

ANSI	*American National Standards Institute*
AS/NZS	*Australian/ New Zealand Standards*
ANPQBS	*Australian National Power Quality Benchmark Survey*
CBEMA	*Computer Business Equipment Manufacturers Association*
CEA	*Canadian Electricity Association*
CENELEC	*European Committee for Electrotechnical Standardisation*
DFT	*Discrete Fourier Transform*
DSI	*Disturbance Severity Indicator*
EHV	*Extra high voltage*
EPRI	*Electric Power Research Institute*
ESKOM	*South African Electricity Supply Company*
FFT	*Fast Fourier Transform*
HV	*High voltage*
IEC	*International Electrotechnical Commission*
IEE	*Institution of Electrical Engineers, UK*
IEEE	*Institution of Electrical and Electronic Engineers, USA*
ITIC	*Information Technology Industry Council*
LTNPQS	*Long Term National Power Quality Survey*
LV	*Low voltage*
MML	*Minimum Message Length*
MV	*Medium voltage*
MVLR	*Multivariable Linear Regression*
NEMA	*National Electricity Manufacturers Association, USA*

P_{st}	*Short term flicker severity index*
P_{lt}	*Long term flicker severity index*
PQAT	*Power Quality Analysis Triangle*
RPM	*Reliable Power Meters*
UPQI	*Unified Power Quality Index*
V	*Voltage (V)*
VUF	*Voltage Unbalance Factor*
V_{THD}	*Voltage Total Harmonic Distortion*