Chapter 1: Introduction

CHAPTER

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CHAPTER 1 – INTRODUCTION: This chapter provides a brief background to engineering problems as well as how power quality affects our everyday life.

1.1 INTRODUCTION

The modern power system is characterised by new levels of sophistication in energy conversion and control. This has introduced non-sinusoidal waveform conditions due to inherent non-linearity of these modern solid-state loads. Non-sinusoidal waveform conditions are only one aspect of a range of so called Power Quality (PQ) phenomena that the modern power system has to contend with.

PQ is defined as any power problem, related to frequency, voltage and current deviations that cause equipment to underperform or fail [1]. Over the last 30 years the United States recorded an exponential increase in the cost of PQ disturbances from $10 million annually to $1000 million annually [1]. According to a study done in Europe, the return-on-investment period for electrical devices has been reduced from an initial value of 30-40 years down to 7-10 years [5]. They have concluded that PQ related problems are costing the European Union €10 billion per annum, and that 5% of this amount is used for the prevention of these problems [5]. These studies indicate that an overall decrease in PQ could imply a major financial loss for both consumers and utilities.

A simple example of modern waveform distortion can be found in energy-efficiency projects such as the use of compact fluorescent lights (CFL). These lights are efficient, however, they use electronic ballasts which cause them to draw non-linear currents from the system. One CFL will not make a big difference, but when the whole country is using them, it is bound to have an effect. The question now is, how great is the effect, what is the duration of the effect and what will the cost be to ensure a quality of supply (QoS) within compatibility limits?

The answer to all of these questions lies in detailed analysis of measured data from a network. Energy prices are on the rise, and more consumers are becoming concerned about the quality of power. Most utilities and municipalities realise this and have started to implement PQ monitoring programs all over their distribution networks in an attempt to start monitoring the QoS. This has resolved into multiple
PQ monitors being installed over their respective networks. The problem now is that they have a lot of measured data, from multiple points, which does not describe the overall PQ of the whole network. For example, if the question was asked: “Did PQ for residential area X increase or decrease?” It may be possible to give an answer, provided that a PQ monitor is embedded in the network and a database was built up over time. However, how will the question, “What is the state of PQ for the South African grid, did it increase or decrease over the years?”, be answered when there are multiple PQ databases containing millions of measurements?

A number of international institutions, including The Institute for Electrical and Electronic Engineers (IEEE), Electrical Power Research Institute (EPRI), International Electrotechnical Commission (IEC) and the National Energy Regulator of South Africa (NERSA) realised that the utilisation of non-linear devices, electrical sensitive equipment and the interconnecting of networks was increasing and the need for a descriptive PQ standard was necessary [1], [6], [15], [17], [18]. Standards are set to protect utilities and consumer equipment from disoperation or failing when there is a deviation in the current, voltage and frequency ratings [1]. The standards set forth by these institutions are to clamp down the boundaries of deviation from normal operation with regards to voltage, current and frequency [1]. They also assist end-user designers in designing their equipment for normal operation within these limits, and utility companies in adopting a good power quality management system (PQMS).

It has become imperative that the QoS is in accordance with national PQ standards and is monitored through regular measurements and data analysis. This is done to ensure that an environment of compatibility exists. Compatibility basically means equipment must operate satisfactorily, without introducing high levels of disturbance in that network where the equipment is connected. A number of the institutions mentioned above have done extensive research to define PQ problems. It is important to realise that these standards were designed to manage levels of distortion at a single point of delivery (PoD) in an electrical network. Numerous points of measurement can exist in a practical network with these PQ recorders distributed all over and at different voltage levels. To translate the vast quantity of recorded data to practical information that can support the business and planning processes of a utility, requires more than the NRS 048 [17], [18] standards on minimum allowable PQ levels.

There are various PQ phenomena and these can be sorted into two groups, namely steady state and transients. This project will focus on steady state phenomena, specifically voltage harmonic distortion on a system. The aim of this project is to investigate benchmarking methods, which can assist the supply industry by integrating multiple data readings into a useful set of information to effectively manage distortion levels across a network.
1.2 ENGINEERING PROBLEM

A significant amount of components from the South African power system infrastructure are relatively old. The compatibility levels (CL) that were used 30 years ago [15], [17], [18] which is still applicable today, did not include the current extent by which non-sinusoidal waveform conditions are being experienced. Development in solid-state electronics has resulted in greater sophistication in energy conversion and energy-efficiency, which found application in a wider range of power levels never seen before. These devices are inherently non-linear and become a source of non-sinusoidal load currents which could result in higher levels of voltage waveform distortion.

The PQ Directive issued by NERSA [15] requires amongst others, the monitoring of distortion levels in a power system. PQ recorders located at various points in a power system effectively records network waveform distortion in a quantitative and qualitative way. The recorded system data have to be translated into management information in order to know the status on waveform distortion. The PQ Directive [15] does not offer any further guidance as to the practical implementation of this analysis.

The South African minimum standards document, NRS 048 [17], [18], describes amongst others, the CL on voltage waveform distortion and individual harmonic components. This document and the metrics used, apply to a single measurement point (PoD) in the network with the intention to verify compliancy of this single PoD to NRS 048 minimum standards. Information on network performance requires an alternative methodology to quantify and qualify waveform distortion as recorded data could be forthcoming from various voltage levels and instruments distributed all over. This research project formulates a methodology to benchmark the harmonic distortion performance of such networks.

The proposed methodology will be tested on field data collected over a 24 month period, results interpreted and proposals for practical application of this method in a PQMS deducted. Possible re-formulation of operational aspects on the management of waveform distortion in the PQ Directive of NERSA will be investigated based on the results obtained.

1.3 RESEARCH METHODOLOGY

There is a growing need to manage the quality of electrical energy effectively. Multiple PQ monitors sample data on a daily basis at various points in the network. Analysis of these data results in distortion indices for a single point and does not reflect distortion levels of the whole network. Integrated analysis must be done to provide managerial information on the whole network. With this
information available, an effective PQMS can be established. An in-depth background study will be done which will cover aspects such as: basic harmonic theory, how harmonics are generated, propagation of harmonics into a power system, harmonic effects and mitigation techniques. The study will also discuss PQ standards with emphasis on the concept of compatibility. Benchmarking techniques and formulas will also be explained. This will provide a solid foundation for the practical implementation of the benchmarking methodology.

The data analysis can be summarised as follows. Firstly, recorded network data will be obtained from Eskom’s database. Additional data will be collected from the network that will be assessed (i.e. population, connected apparent power etc.). The necessary formulas and algorithms will be programmed into MathCAD. The network data will then be imported and results obtained. A discussion and conclusion will follow.

1.4 DISSERTATION LAYOUT

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