STUDIES OF POWER QUALITY: DISTURBANCE RECOGNITION

M. Negnevitsky    K. Debnath    J. Huang    M. Ringrose
School of Engineering
University of Tasmania
HOBART Tasmania

Abstract

The issue of Power Quality is very important to both the consumers and the distributors of electric power. There are many facets of power quality disturbances and each has its own source and mitigation techniques. The first step towards any solution for a disturbance is to recognize the presence of a particular type of disturbance and locate its source. Conventional methods for recognition of a power quality disturbance consists of collecting operating data, inspecting the wave forms visually and then identifying any disturbance that may be present in the data. Although the available measuring and recording devices offer substantial help, the process is, in the main, very slow. At the University of Tasmania, a project is under way to automatize this process. The ultimate goal is to develop an Automatic Disturbance Recognition System (ADRS). In its current state, tests with simulated as well as real disturbance data yielded encouraging results, some of which are presented in this paper.

1 INTRODUCTION

The quality of electric power is becoming a matter of increasing concern to both power utilities and their customers. There are a number of major reasons for this. They are:

1. Customer equipment today are more sensitive to power quality variations than equipment used in the past. Modern microprocessor-based controllers and power electronic devices are very sensitive to various disturbances in the power supply.

2. Increasing levels of harmonics in power systems give rise to concerns about the future impact on the system performance.

3. Customers are becoming better informed about power quality problems and are challenging the utilities to improve power quality.

Power quality may deteriorate due to a variety of reasons. In order to maintain a reasonable level of quality, it is necessary to identify the disturbance causing a particular type of power quality problem and to locate the sources of that disturbance in the power system so that corrective action can be taken. Existing methods of analyzing and identifying power disturbances are laborious since they are based on visual inspection of disturbance waveforms. Due to the complexity of power quality problems and the lack of reliable techniques to analyze these problems, power utilities are unable to ensure the required level of power quality without a considerable increase in cost. An automated system for disturbance recognition and classification will have many advantages over a manual system. These advantages include the speed of processing, amount of data that can be processed, ease of data collection and storage, reliability and cost. Currently, no reliable automatic system exists for classifying a broad range of disturbances. Several methods for automated detection and classification of a single type of disturbances have been proposed recently. In particular, disturbances due to faults and transformer inrush [1,2,3], but these are limited in their application. However, there have also been a number of papers dedicated to automatic recognition of power system disturbances. The main feature of this research is the use wavelet transforms and artificial neural networks [4,5].

2 WHAT IS POWER QUALITY

Power quality or, in fact, lack of quality is a term used to describe the most important aspect of the electricity supply. Power quality can be defined as any problem manifested in voltage, current, or frequency deviation that results in failure or mal-operation of electric equipment [6]. It covers several types of problems of electricity supply and power system disturbances. A short description of each individual power quality problems is given below:

Voltage Sag: A decrease of the RMS voltage to 0.1–0.9 pu for a duration of 0.5 cycle to 1 minute.
Voltage Swell: An increase of the RMS voltage to 1.1~1.8 pu for a duration of 0.5 cycle to 1 minute.

Momentary Interruption: A decrease of the RMS voltage to less than 0.1 pu, for a duration of 0.5 cycle to 1 minute.

Voltage Fluctuation: Variation of voltage envelop between 0.9 pu to 1.1 pu.

Capacitor Switching Transients: A sudden non-power frequency change in the steady state of voltage.

Impulsive Transients: A sudden non-power frequency change in the steady state of voltage with duration typically in order of tens of microsecond.

Harmonics: Sinusoidal voltage having frequencies that are integral multiples of power frequency.

Frequency Deviation: An increase of the power frequency to 104~110% of nominal frequency or a decrease to 90~96% of nominal frequency.

Notch: A switching disturbance of the normal power voltage waveform, which is of opposite polarity to the waveform with each notch lasting less than 0.5 cycle.

Noise: Unwanted electrical signals superimposed upon voltage with broadband spectral content lower than 200kHz

DC Offset: A dc component of 0~0.1 pu superimposed on the RMS voltage.

A normal waveform can, therefore, be visualized as one devoid of any of the above power quality problems. In essence a normal waveform is a power frequency (50 Hz) sinusoidal waveform with RMS voltage within 0.95-1.05 pu.

3 RESEARCH AT UNIVERSITY OF TASMANIA

In Australia, University of Tasmania has been at the forefront of research in Power Quality. Researches here have been active in this field for a number of years. A project called “Quality of Electricity Supply” was undertaken in 1996. In the first phase of the project, a survey was conducted among the major players in the electricity industry in the state of Tasmania viz. Power utility and major customers. This survey revealed their perceptions about the existing power quality. It was observed that the power utilities and the power users look at the power quality problems in different ways. Figure 1 shows such a case. In this figure, it is shown that in the perception of the utility (HEC), power outages is the major problem in Tasmania while the customers think that momentary and temporary interruptions are equally common. In other types of PQ problems, the feelings were not as divergent.

In the second phase of the project, an extensive program of measurements was carried out throughout the state of Tasmania. Measurements were carried out at the sites of major industrial customers. A special experiment was conducted when five disturbances were triggered at different locations throughout the state in order to monitor harmonic propagation through the Tasmanian power system. Monitoring was simultaneously carried out at five different locations.

In total, measurements were carried out at 29 different locations for more than 181 hours of effective measurements over 21 days. A few of the observations of that survey is provided below.

Voltage sags and swells were also recorded at different locations. Several voltage impulses and wave shape faults were also recorded at different locations.

Maximum voltage flickers recorded were between 0.196% and 1.393%.

No significant current or voltage imbalances were recorded. Maximum current imbalances were around 7.6% and maximum voltage imbalances were 1.3%. No significant ground or neutral currents were recorded at any location.

At most locations, the monitoring period was 12 hours, and overall, the locations had a THD of less than 2.0% for 95% of the time. On one site, however, during the monitoring period of three hours, the maximum voltage THD of 6.98% was recorded while the average voltage THD was about 3%, which is outside the limits specified in national [7] and international [8] standards for THD.

Dominant harmonics identified at most locations were 5\textsuperscript{th}, 7\textsuperscript{th} and 11\textsuperscript{th}. At some locations, maximum recorded amplitudes of the 5\textsuperscript{th}, 7\textsuperscript{th} and 11\textsuperscript{th} harmonics were well.
above 3%, the limit specified for individual harmonics.

The major source of the problems with power quality at the customer site identified by the utility is arc welding devices. The next group of potential problem sources consists of UPSs and rectifiers, as viewed by the utility. As far as industry is concerned, by far the major sources of problems are rectifiers and variable speed drives. The detailed results of the project have already been published [9].

The summary of power quality can be presented as the Power Tolerance Envelope developed by Computer Business Equipment Manufacturers Association (CBEMA). The CBEMA curve represents a de facto standard in the area of power quality. A dot on the CBEMA graph represents an event. A dot in the area outside the envelope depicts an event associated with power quality deviation. During the monitoring period, voltage deviations i.e. points outside of the CBEMA were recorded at some locations. An illustrative example for such an event is presented in Fig. 2.

![Figure 2 An event outside the CBEMA curve.](image)

4 DISTURBANCE RECOGNITION SYSTEM

The work performed at the University of Tasmania in the past and described above was done by analyzing the data manually and by visual inspection of the waveform. This method is labourious and time consuming. In order to get rid of visual inspection of the waveforms, an automated method is required. This will involve the integration of signal processing and artificial intelligence techniques like neural networks, fuzzy logic. A new signal processing tool i.e. Wavelet transform is also added to the arsenal of automatic power quality disturbance recognition. The artificial intelligence techniques are used for decision making. This integration gives rise to an automatic disturbance recognition system (ADRS).

The ADRS will receive data online, process them and will be able to determine whether there is a PQ disturbance in the particular group of data. In the event that there is a disturbance, the system will also be able to classify the type of disturbance. The components of the ADRS are shown in Figure 3.

4.1 Modeling for the ADRS

In order to train the Automatic Disturbance Recognition System, a large database of disturbance waveforms is required. There are two possible sources for these waveforms. The preferable source of disturbance data is from recording actual disturbances in the power system. However, it is clear that only a small percentage of possible disturbances will occur in the power system over any given period of time. This means that the source of the majority of disturbance data is from simulation.

The source of a recorded disturbance also has to be identified so that the recognition system can be trained to identify similar disturbances as coming from that source. If the source of the disturbance is not obvious, then it can be compared to similar simulated disturbances to locate the source.

Suitable models must be constructed for each category of disturbance the ADRS is to recognize. These include load flow and fault analysis for long duration disturbances, harmonic models and higher frequency models for transient disturbances. In the majority of cases, only the local area around the disturbance source need be included into the model in detail.

Relatively detailed load models are a requirement for good power quality simulation. The possible disturbances that a load can create must be understood as well as a load’s response to external disturbances.

To date, a comprehensive 3-phase harmonic model of the Tasmanian high voltage transmission network has been constructed. The results produced by this model have been compared to a series of measurements that were taken and analyzed to determine the relative contribution of harmonics at different locations, from different sources.
5 SOME RESULTS

The system was tested with data containing known disturbances. The percentage of successful recognition of the various types of disturbances are listed in Table 1. It may be noticed in this table that for different types of disturbances, the success rate varies from 93 to 100 percent except for the noise. This may further be improved if the data is further processed. Work is presently going on towards this direction. The relatively poor success rate in the recognition of noise is due to the low sampling frequency adopted in capturing the distorted waveforms. It is expected that with the increase of sampling rate, the success will also improve.

There is no space here to provide comparisons of all the disturbance types. However, the comparison of one type of power quality deviation viz. Harmonics is shown in Figure 4. This figure shows harmonics only up to the 22nd, but the system can identify much higher order of harmonics. Figure 4 demonstrates that the ADRS can not only recognize the presence of harmonics correctly, it can also compute the magnitudes of the individual harmonics to a surprising degree of accuracy.

6 SUMMARY & CONCLUSIONS

The problems of power quality deviation have been discussed in this paper. Some results of measurements in the Tasmanian power system have been mentioned. It brief description of the automatic disturbance recognition system has been provided. Some work has already been done on this and further work is going on. Results from preliminary works with simulated data has been very encouraging. Sample results have been provided in this paper. It is expected that with further research, the ADRS will become a tool for near-perfect identification of all types of power quality disturbances.

7 REFERENCES


