DESIGN AND DEVELOPMENT OF REAL TIME POWER QUALITY MONITORING SYSTEM

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“I hereby declare that I have read through this report entitle “Design and Development of Real Time Power Quality Monitoring System” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”.

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Date	:	....

“I declare that this report entitle “Design and Development of Real Time Power Quality Monitoring System” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree”.

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ABSTRACT

The increasing of sensitive electrical equipment in our technologies is the biggest issues contributor to power line system. The quality of electrical power supplied becomes more concern to customers or electric users. The power quality events will affect manufacturing process, failure of equipment and economic losses. The developments that have been used today are not user friendly and costly. In addition, the equipment that available in the market cannot monitor and stored the data efficiently. Then, the user cannot check the performance of the power line system. This project presents a design and development of real time power quality monitoring system. The system can measure, display and record parameters as well as classify power quality signals from power line system. The measured parameters are calculated from voltage and current signal such as root mean square (RMS) voltage and current, real power, apparent power, reactive power, frequency and power factor. In addition, by using these parameters, the power quality signals such as swell, sag, interruption, under voltage and over voltage are classified based IEEE standard 1159-2009. The voltage and current signals are captured by using NI USB 6009 data acquisition (DAQ) system to convert the analogue signal to digital and then transfer to computer. The DAQ system is chosen because some of its characteristic available gives great advantages upon its usage for this project. Small and portable of physical size can easily bring and move from one place to another place. In addition, the usage of USB as a communication link between personal computer and NI USB 6009 is convenient for either use with laptop or desktop, thus no external supply is needed because it is powered by USB. Besides that, user friendly software is developed on computer by using Visual Basic 2006 to calculate, display, classify and record the power quality signals parameters. This project also shows high accuracy monitoring system that presents very low absolute percentage error (APE) measurements and suitable for power quality monitoring purpose.

ABSTRAK

Peningkatan peralatan elektrik yang sensitif dalam teknologi terkini menyumbang masalah terbesar dalam sistem talian kuasa. Kualiti bekalan kuasa elektrik menjadi perhatian yang lebih kepada pengguna atau pengguna elektrik. Isyarat kuasa elektrik akan mempengaruhi proses pengeluaran, kegagalan peralatan dan kehilangan ekonomi. Pembangunan sistem yang digunakan hari ini tidak mesra pengguna dan mahal. Selain itu, peralatan yang berada di pasaran tidak dapat memantau dan penyimpan data dengan cekap. Pengguna juga tidak dapat memeriksa kemajuan sistem talian kuasa. Projek ini menunjukan sebuah rekabentuk dan pembangunan pemantau kualiti kuasa masa nyata. Sistem ini dapat mengukur, memapar dan merekod parameter dan juga mengklasifikasi isyarat kualiti kuasa daripada sistem talian kuasa. Parameter yang diukur dikira daripada isyarat voltan dan arus seperti voltan dan arus RMS, kuasa sahih, kuasa reaktif, kuasa ketara, frekuensi dan factor kuasa. Selain itu, dengan menggunakan parameter ini, isyarat kualiti kuasa seperti membengkak, mengendur, gangguan, voltan tinggi, voltan rendah diklasifikasikan berdasarkan standard IEEE 1159-2009. Isyarat voltan dan arus diambil dengan menggunakan NI USB 6009 pengambilan alihan data (DAQ) untuk menukar isyarat analog kepada diskret dan kemudiannya dihantar ke komputer. DAQ sistem dipilih kerana kriteria yang ada memberikan kelebihan penggunaan untuk projek ini. Fizikal kecil dan boleh ubah dengan mudah dibawa dari satu tempat ke tempat yang lain. Selain itu juga, penggunaan USB sebagai jaringan komunikasi di antara komputer dan DAQ adalah mudah samada untuk penggunaan komputer. Oleh itu, bekalan luaran tidak diperlukan kerana ianya dibekalkan oleh kuasa dari USB. Selain itu, Perisian mesra pengguna dibangunkan di komputer dengan menggunakan Visual Basic 2006 untuk mengira, memapar, mengklasifikasi dan merekod parameter isyarat kualiti kuasa. Projek ini juga menunjukkan ketepatan yang tinggi dimana memberikan peratus ralat mutlak yang sangan rendah perngukuran dan sesuait digunakan untuk tujuan pemantauan kualiti kuasa.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The rapidly growing use of electrical equipment in our technologies is the biggest contributor to power quality problem. The electrical power quality of power system has become an important issue and heightened of awareness of power quality among the electricity users [1]. The ability to maintain voltage and current signals with constant amplitude and constant fundamental frequency presents the quality of electrical power supplied to the customers [2]. The small interruption of power quality event can cause equipment failure and economical loss. The power quality events are voltage swell, voltage sag, under voltage, over voltage, interruption, harmonic, interharmonics, transient and notching [3].

Monitoring and analysis of power line waveforms are assessment of power quality events. It's essential to measure voltage, current, frequency, harmonic distortion and waveform to monitor the power quality. The use of power quality monitoring is to locate the source of the events that occurs. Some of monitoring system applied is Data acquisition board or DSP processor for monitoring power quality in real time [4]. The monitoring and analysis of power quality process are very important to overcome and provide improvement in power system infrastructure.

The parameters of the power quality are characterized by voltage signal in RMS value (voltage and current), frequency, real power, reactive power, apparent power and power factor. The classification analysis is developed using based expert system in Visual Basic 2006. On the other side, this monitoring system proof that the quality of the offered power is within the pre-specified standards and analysis and record the data or information for solving problems. Existing power quality monitoring needs improvement on their capability, efficiently, reliability and accuracy [2].

This project presents a design and development of real time power quality monitoring system. The system can monitor record and analyze the data from power line. All the parameters that can be measured are voltage (rms), current (rms), frequency, real power, reactive power, apparent power and power factor. The data will be recorded and stored efficiently. As results, the performances of the power line system can be monitored and analyzed.

1.1 Problem Statements

With the increase of loads sensitive to power disturbances and the drive to gain profits, power quality has become a great concern. Sophisticated electronics devices are being rapidly introduced into the market such as computers, telecommunications and electronic process controls. All of these modern technologies require stable power supply in order to achieve optimum reliability, compared to the oldest equipments. Any slight disruptions in a power line can cause losses up to millions in an operating factory.

For the past 20 years, awareness of the power-quality problem has greatly improved, with a report from *Business Week* (1991) stating that spikes, sags and outages cost the US nation US$26 billion in downtime [14]. Contributing to this cost is lost time, lost production, lost sales, delivery delays and damaged production equipment. Therefore, there is a need to understand and improve the power quality problems. The source of the power quality problem is not given, an unacceptable quality of power may be a utility's responsibility of the industrial facility.

The power quality events will affect many industries that can interrupt manufacturing process, failure of equipment and economic losses. Before this, the user only use the electricity but unknown of voltage and current that insert to the loads. The measurements are taken by multimeter and the reading is taken manually. This will cause an error when taking the readings. Other than that, the equipments in market nowadays can only capture and print the data. In addition, the data cannot be monitor and stored efficiently. Then, the user can not check the performance of the power line system. The developments that have been used today are not user friendly and costly.

1.2 Project Objectives

The objectives of the project are:

1. To develop user friendly real time power quality monitoring system that can measure and display power line parameters such as voltage (V), current (I), frequency (f), real power (P), apparent power (S) and power factor (pf) on the computer in real time.

2. To classify power quality signals such as normal, swell, sag, interruption, under voltage and over voltage. The signals are classified based on IEEE standard 1159-2009.

3. To analyze and verify the performance of the monitoring system. The system is tested using real signals and the results are evaluated in terms of accuracy of the measurements.

1.3 Project Scopes

This project is developed using NI USB 6009 DAQ Card and Visual Basic 6.0 program on computer. The scopes consists of:

1. This system utilize the Microsoft Visual Basic 2006 software and NI USB-6009 Data Acquisition Card (DAQ card).

2. This project can measure voltage (rms), current (rms), frequency, real power, reactive power, apparent power and power factor.

3. This system only classify 6 types of power quality signals which are normal, swell, sag, interruption, over voltage and under voltage based IEEE 1159-2009.

4. Voltage and current signals are measured between 0 to 300 Vrms and 0 to 100 Ampere for single phase power line.

Due to time limitations, the scope of this project does not include measuring the voltages and current in a three phases and high power line.

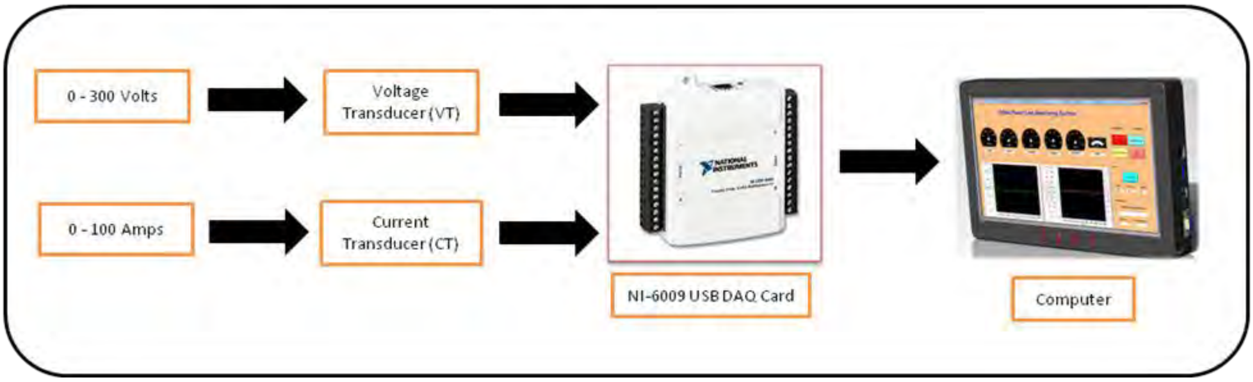


Figure 1.0: Block diagram of the project

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is a body of text that aims to review the idea and understanding about real time power quality monitoring system. This chapter describes the power quality events, power quality measurement and power quality monitoring.

2.2 Power Quality

There is a need to elevate awareness among electricity users regarding power quality events due to frequent recurrences of the problems [1]. In addition, power quality measurement system is essential in order to perform quick measurement system and reliable power quality monitoring. The power quality signals include voltage sags, voltage swell, undervoltage, overvoltage, interruption, interharmonic, harmonic, notching, and transient according to IEEE Std. 1159-2009. Based on the International Electrotechnical

Commission (IEC), electromagnetic phenomena are classified into several groups as shown in Table 2.1.

Table 2.1: Categories and Typical Characteristics of Power System Electromagnetic Phenomena

Categories	Typical spectral content	Typical duration	Typical voltage magnitude
1.0 Transients			
1.1 Impulsive			
1.1.1 Nanosecond	5 ns rise	< 50 ns	
1.1.2 Microsecond	1 ms rise	50 ns-1 ms	
1.1.3 Millisecond	0.1 ms rise	> 1 ms	
1.2 Oscillatory			
1.2.1 Low frequency	< 5 kHz	0.3-50 ms	0-4 pu
1.2.2 Medium frequency	5-500 kHz	20 ms	0-8 pu
1.2.3 High frequency	0.5-5 MHz	5 ms	0-4 pu
2.0 Short duration variations			
2.1 Instantaneous			
2.1.1 Sag		0.5-30 cycles	0.1-0.9 pu
2.1.2 Swell		0.5-30 cycles	1.1-1.8 pu
2.2 Momentary			
2.2.1 Interruption		0.5 cycles -3 s	< 0.1 pu
2.2.2 Sag		30 cycles-3 s	0.1-0.9 pu
2.2.3 Swell		30 cycles-3 s	1.1-1.4 pu
2.3 Temporary			
2.3.1 Interruption		3 s-1 min	< 0.1 pu
2.3.2 Sag		3 s-1 min	0.1-0.9 pu
2.3.3 Swell		3 s-1 min	1.1-1.2 pu
3.0 Long duration variations			
3.1 Interruption, sustained		> 1 min	0.0 pu
3.2 Undervoltages		> 1 min	0.8-0.9 pu
3.3 Overvoltages		> 1 min	1.1-1.2 pu
4.0 Voltage imbalance		steady state	0.5-2%
5.0 Waveform distortion			
5.1 DC offset		steady state	0-0.1%
5.2 Harmonics	0-100th H	steady state	0-20%
5.3 Interharmonics	0-6 kHz	steady state	0-2%
5.4 Notching		steady state	
5.5 Noise	broad-band	steady state	0-1%
6.0 Voltage fluctuations	< 25 Hz	Intermittent	0.1-7%
7.0 Power frequency variations		< 10 s	

The power quality refers to variation of electromagnetic phenomena that distinguish the voltages and currents at a stipulated time and location. The common practice to monitor power quality is generally based on visual inspection of voltage and current waveforms identification [5]. Classification of power quality events, existing problem solving and future problem anticipation can be detected with the monitoring system. Other than that, conversion of analog voltages and currents in the power system to sampled digital values can be processed automatically using power quality monitoring. Once quality events are detected, they are classified into known waveforms for data recording and analysis. The result of the data recording and analysis can assist in determining the causes as well as solutions to mitigate these disturbances.

2.3 Power Quality Events

There are several common power quality events in power line system. It is normally divided into 5 categories. They are [15]:

i. Transients

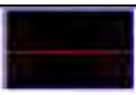
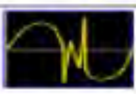
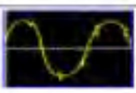
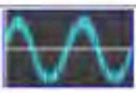
ii. Waveform Distortions

iii. Short Duration Voltage Variations

iv. Long Duration Voltage Variations

v. Interruptions

Table 2.2: Categories and Typical Characteristics of Power Quality Signal

Temporary Interruption		Planned or accidental total loss of utility power in a localized area of the community. Seconds to minutes	Equipment shutdown, loss of work and data, file and hard disk and operating system (OS) corruption, loss of fiber optic, T1 and ISDN connections	Off-line - Yes Line-interactive - Yes On-line - Yes
Long-Term Interruption		Planned or accidental total loss of utility power in a localized area of the community. Minutes to hours	Equipment shutdown, loss of work and data, file and hard disk and OS corruption, loss of fiber optic, T1 and ISDN connections	Off-line - No Line-interactive – 95% No On-line - Yes
Momentary Interruption		Very short planned or accidental power loss Milliseconds to seconds	Computer hangs, computer and network equipment reboots or hangs, loss of work and data, file and hard disk and OS corruption	Off-line - Maybe Line-interactive - Maybe On-line - Yes
Sag or Under-Voltage		A decrease in utility voltage Sags – Milliseconds to a few seconds • Under-voltage – Longer than a few seconds	Shrinking display screens, equipment hang or reset, equipment power supply damage, Computer hangs, computer and network equipment reboots or hangs, loss of work and data, file and hard disk and OS corruption	Off-line - No Line-interactive - Yes On-line - Yes
Swell or Over-Voltage		An increase in Utility voltage Swell – Milliseconds to a few seconds • Over-voltage – Longer than a few seconds	Permanent equipment damage, Computer hangs, computer and network equipment reboots or hangs, loss of work and data, file and hard disk and OS corruption	Off-line - No Line-interactive - Yes On-line - Yes
Transient, Impulse or Spike		A sudden change in voltage up to several hundred to thousands of volts Microseconds	Network Errors, Burned or damaged equipment and circuitry, Computer hangs, computer and network equipment reboots or hangs, loss of work and data, file and hard disk and OS corruption	Off-line - Yes Line-interactive – Yes On-line – Yes, Higher level of protection
Notch		A disturbance of opposite polarity from the waveform Microseconds	Slow LAN due to excessive errors, audible noise in telephone and audio equipment	Off-line - No Line-interactive - No On-line - Yes
Noise		An unwanted electrical signal of high frequency from other equipment Sporadic	Slow LAN due to excessive errors, audible noise in telephone and audio equipment. Equipment hangs.	Off-line - No Line-interactive - No On-line - Yes
Harmonic Distortion		An alteration of the pure sinewave (sinewave distortion), due to non-linear loads such as computer switching [illegible]	Causes motors, transformers and wiring to overheat, lowers operating efficiency of office equipment.	Off-line - No Line-interactive - No On-line - Yes

2.3.1 Transients

A transient in power quality is used to denote an event that is undesirable but momentary in nature. The first thing that comes to mind to most power engineers is the notion of a damped oscillatory transient due to RLC network when they hear the word transient. In a broader aspect, a transient simply brings the meaning 'that part of the change in a variable that disappears during transitions from one steady state operating condition to another. Generally, transients can be classified into two categories, which are impulsive transient and oscillatory transient.

2.3.1.1 Impulsive Transient

Impulsive transient means a sudden and short duration disturbance by a very rapid change in the steady-state condition of voltage, current, or both, that is unidirectional in polarity either positive or negative. The most common cause of impulsive transients is lightning. Peak currents from lightning strikes can exceed 200kA with 10/350 µsec duration. The frequency range is more than 5kHz considered in the high frequency category. The duration of impulsive transient is from 30-200µsec, and generally occurs along utility lines. The occurrence of an impulsive transient can lead to transformer failures, arrester failures and damages to customer equipments. Figure 2.1 shows waveform of impulsive transient.

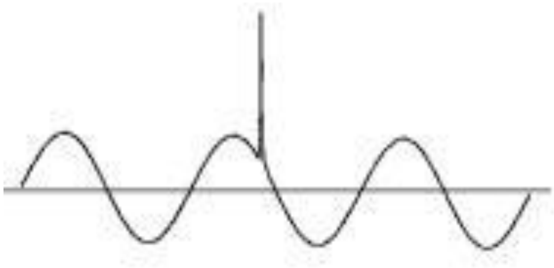


Figure 2.1: Impulsive Transient