A SMART POWER QUALITY (PQ) CLASSIFICATION VIA GUI

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DECLARATION

I declare that this report entitle "***A Smart Power Quality (PQ) Classification via GUI***" 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 the candidature of any other degree.

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APPROVAL

I hereby declare that I have read through this report entitle "**A Smart Power Quality (PQ) Classification via GUI**" and found that it has complied the partial fulfillment for awarding the Bachelor in Electrical Engineering (Industrial Power)

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ABSTRACT

Power quality (PQ) is among the main things that is emphasized and is taken into consideration by utilities in order to meet the demands. At each passing day this issue has becoming more serious and at the same time the user's demand on power quality also gets more critical. The increased of power electronics equipment that are more sensitive to minor voltage really give a huge impact on PQ. Therefore, system that has a good and understandable interface should be developed to detect and classify the quality level of voltage in distribution system for recovering process. In order to achieve that, a technique that called phase space has been developed in matrix laboratory (MATLAB) graphical user interface (GUI) as presented in this thesis. Twelve different types of PQ disturbances under different conditions have been tested using the proposed scheme to detect and classify the disturbances. The results indicate that the proposed PQ detection method can effectively detect, classify and display the types of occurred disturbances through GUI.

ABSTRAK

Kualiti kuasa (KK) adalah antara perkara utama yang ditekankan dan diambil kira oleh utiliti untuk memenuhi permintaan pelanggan. Sejak kebelakangan ini, isu KK telah menjadi lebih serius dan pada masa yang sama permintaan pengguna terhadap kualiti kuasa juga menjadi lebih kritikal. Peningkatan peralatan elektronik kuasa yang lebih sensitif kepada voltan kecil benar-benar memberi kesan yang besar terhadap KK. Oleh itu, satu sistem yang mempunyai antara muka yang baik dan mudah difahami perlu dibangunkan untuk mengesan dan membezakan tahap kualiti dalam sistem pengagihan untuk proses membaik-pulih. Untuk menjayakannya, satu teknik yang dipanggil ruang fasa telah dibangunkan dalam makmal matriks (MATLAB) grafik antara muka pengguna (GUI) seperti yang dinyatakan dalam tesis ini. Dua belas jenis gangguan KK di bawah keadaan yang berbeza telah diuji menggunakan teknik yang dicadangkan dan keputusan membuktikan bahawa teknik tersebut berfungsi dengan baik dalam mengesan dan mengklasifikasikan KK. Hasil kajian menunjukkan bahawa kaedah pengesanan KK yang dicadangkan berhasil untuk mengesan, mengelaskan dan memaparkan jenis gangguan yang berlaku melalui GUI.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Power Quality (PQ) has becoming a very important even to be concerned by customers especially industrial sectors nowadays. The load variations, load switching, system faults motor starting and non-linear loads are usually will create disturbances in power quality [1]. Flicker, interruptions, sag, swell, under voltage and over voltage are some of electrical disturbances due to the phenomenon above.

For utility companies, power quality really makes a huge impact if it is not controls well. The quality level of voltage is the most importance before it can be supplied to customers. To make sure the quality level of voltage is acceptable, the utilities should recognize first the level of voltage that will be used by customers and if the voltage level is unacceptable, the voltage treatment should be done by detecting and classifying type of PQ.

In this thesis, it shows how PQ disturbances are being detected and classified using the phase space technique. By implementing the technique in MATLAB, the disturbances including sag, swell, interruptions, under voltage and over voltage will be processed and then displayed through the interface that has been developed via GUI.

1.2 Problem Statement

Power Quality problems has been a source of major concern in recent years due to extensive used of power electronic devices and non-linear loads in electrical power system which have led to large growth in the number of voltage disturbances. To monitor the disturbances, many techniques have been implemented and a common way to detect and classify the disturbances is based on frequency-based approach such as discrete Fourier transform (DFT) and wavelet transform (WT). However, these techniques have some limitations. Even DFT has a great application to periodic signals but it fails to track a transient signal due to the limitation of a fixed length window length [2]. So, DFT cannot be used successfully for high frequency components. For WT, it is able to identify the details of localized transient but it required a sampling window of a certain length to perform integral calculations which increases the computational burden and impairs its attraction [2]. Besides that, artificial intelligence-based algorithms also has been proposed for disturbances detection. This technique can provides a satisfactory classification results but it relies on massive data for training which greatly limits the practical application [3]. It seems that phase space technique is the best choice for monitoring the disturbances due to this technique can be used to classify all the PQ events just by analyse the shape (ellipse) of the voltage signal that has been transformed from original voltage waveform [3].

Meanwhile, a lot of software are applicable in displaying the detected disturbances through an interface such as common line interface (CLI) and menu-driven user interface. CLI is flexible in completing an interface task even for a complicated one. However, due to a lot of syntax should be remembered to perform a task, it will caused human error that can affects the results [4]. For menu-driven user interface, user is provided with a hierarchically organized set of choices but if the structure of menu is complex, users will fail to correctly perform a task on a menu [5]. Development on interface software has been improved from time to time and MATLAB GUI is one of them. It is the best graphical user interface due to the guidance of menu-based that has installed in MATLAB GUI which has reduced the difficulty of remembering the syntax. So that the system has easier users to perform a task and at the same time will reduces human error [4].

1.3 Objective

The objectives of this project are listed below:

i. To develop system that will detect and classify the quality level of voltage in distribution system in Malaysia for single phase and three phase via phase space technique.
ii. To develop an easy interface to read by customers via MATLAB GUI for power quality disturbances (voltage quality level).

1.4 Scope of Project

This project monitored the quality level of voltage in distribution system where MATLAB GUI processed the voltage signals through phase space technique. The voltage signals data that obtained from Tenaga Nasional Berhad (TNB) are saved in text format (.txt) first before processed by a system (MATLAB GUI). The system only specialized to classify the quality of voltage level for 230V (+10% -6%) and 400V (+10% -6%) according to standard that has been decided by TNB for single phase and three phase system in Malaysia. Apart from that, this system is built to only locate, identify and classify normal voltage and twelve voltage disturbances which are instantaneous short duration variations (interruption, sag and swell), momentary short duration variations (interruption, sag and swell), temporary short duration variations (interruption, sag and swell) and long duration variations (interruption, under voltage and over voltage).

1.5 Report Outline

There are 5 chapters in this research project. For **Chapter one**, it is discussed about the introductory of this project. Then for **Chapter two**, the parameters of literature reviews which are power quality (PQ), technique in classifying power quality interruption and previous research are discussed. Methodology is in **Chapter three** where the steps in achieving the objectives of this research is detailed discussed. Starting with locate the voltage signal, transform the voltage signal through phase space technique and process the voltage signal via GUI. In **Chapter four**, the result of the tested voltage signals are explained in there. For the last chapter **(Chapter five)**, conclusion on this project is literally pointed out.

CHAPTER 2

LITERATURE REVIEW

2.1 Power Quality (PQ)

Power Quality (PQ) is a term used that can disrupted or damaged sensitive electronic device [5]. Ideally, the best electrical supply would be a constant magnitude and frequency sinusoidal voltage waveform. However, because of the non-zero impedance of the supply system, of the large variety of loads that may be encountered and of other phenomena such as transients and outages, the reality is often different. If the PQ of the network is good, then any loads connected to it will run satisfactory and efficiently. Installation running costs and carbon footprint will be minimal. If the PQ of the network is bad, then loads connected to it will fail or will have a reduced lifetime, and the efficiency of the electrical installation will reduce. Installation running costs and carbon footprint will be high and/or operation may not be possible at all.

2.2 PQ Characterization

Power Quality can be characterized into several types based on the amplitude and duration of occurrence (frequency) of the voltage signal. Some of types of PQ have the same amplitude but differ in the duration of occurrence. Apart from that, there are also types of PQ that have the same duration of occurrence but differ in the amplitude. The types of PQ characterization based on amplitude and duration of occurrence is shown in Table 2.2.

Table 2.2: Typical PQ characters [6]

Item	Categories	Typical Duration	Typical Voltage Magnitude
1.0	Short Duration Variation (Instantaneous)		
	- Interruption	0.5 – 30 cycles	<0.1 p.u
	- Sag (dip)	0.5 – 30 cycles	0.1 - 0.9 p.u
	- Swell	0.5 – 30 cycles	1.1 – 1.8 p.u
2.0	Short Duration Variation (Momentary)		
	- Interruption	30cycles – 3s	<0.1 p.u
	- Sag (dip)	30cycles – 3s	0.1 - 0.9 p.u
	- Swell	30cycles – 3s	1.1 – 1.4 p.u
3.0	Short Duration Variation (Temporary)		
	- Interruption	3s – 1min	<0.1 p.u
	- Sag (dip)	3s – 1min	0.1 - 0.9 p.u
	- Swell	3s – 1min	1.1 – 1.2 p.u
4.0	Long Duration Variation		
	- Interruption sustained	>1min	<0.1 p.u
	- Under voltages	>1min	0.1 – 0.9 p.u
	- Over voltages	>1min	1.1 – 1.2 p.u

2.2.1 Voltage Sag

Voltage sag is one of the common disturbance in voltage signal. Typically, large loads such as an electric motor or an arc furnace can create a voltage sag [7]. By definition, voltage sag is an event that can last from half of a cycle to several seconds depends on the types of voltage sag whether short instantaneous, momentary or temporary. The magnitude of voltage sag is lower than the normal (pure) voltage signal. Figure 2.2 shows the voltage signal during sag event.

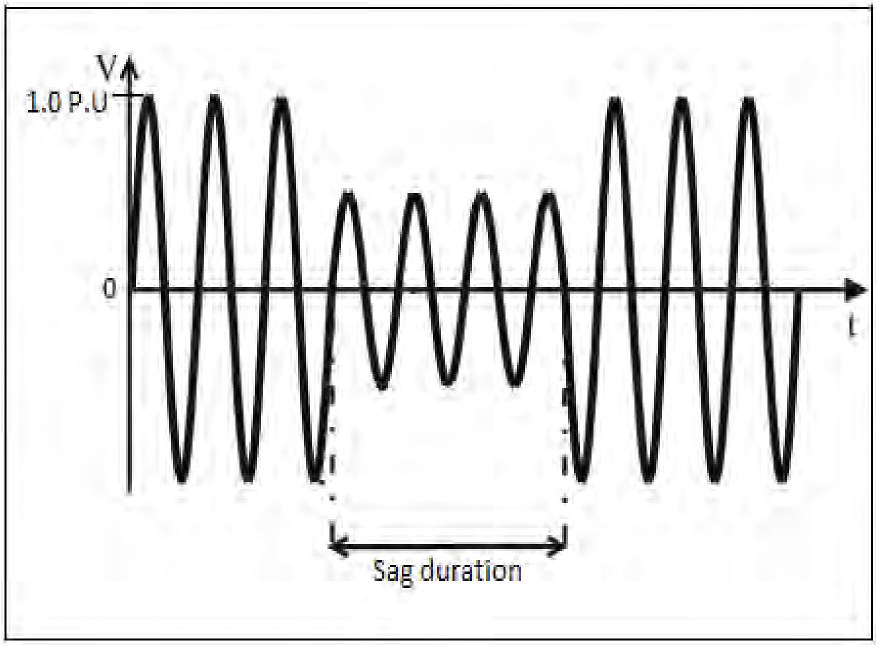

Figure2.2: Voltage sag signal

2.2.2 Voltage Swell

Swell normally related to system fault conditions but is not as common as voltage sag. Energizing a large capacitor bank and switching off a large load can caused swell [8]. Differ with sag, swell is the increment of voltage signal above than normal. A different types of swell category will have a different value of voltage magnitude and the duration as stated in Table 2.1. Instantaneous swell is the shortest duration followed by momentary swell and the longest swell event is temporary swell. Figure 2.3 shows the signal of voltage during swell event.

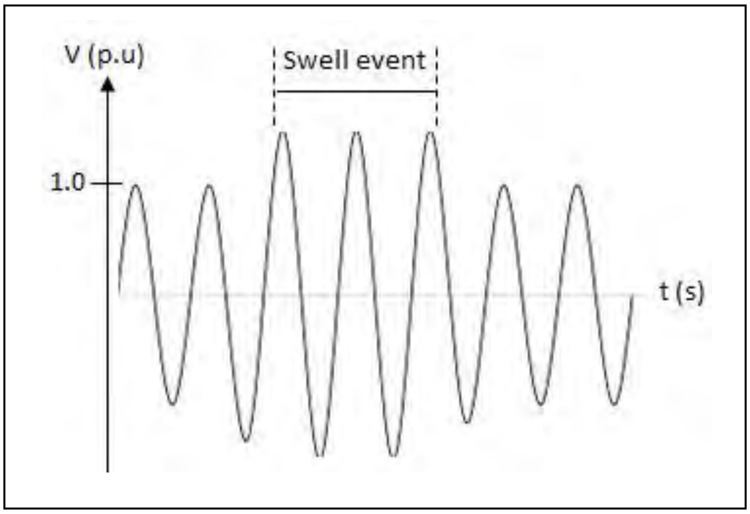

Figure 2.3: Voltage swell signal

2.2.3 Interruption

Interruptions can be the result of power system faults, equipment failures, and control malfunctions [8]. During interruption, the voltage magnitude is always below than ten percent of nominal while the duration is specified according to the types of interruption whether instantaneous, momentary, temporary or interruption sustain. Figure 2.4 shows the signal of voltage during interruption.

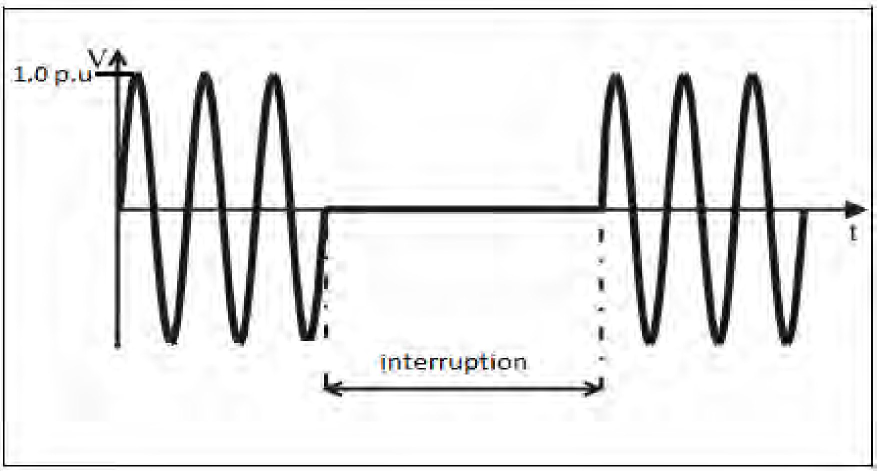

Figure 2.4: Interruption signal

2.2.4 Undervoltage

An under voltage is a decrease of ninety percent of voltage amplitude from nominal. Even has the amplitude as sag, however the duration of undervoltage more than one minute. Undervoltages are the result of switching events that are the opposite of the events that cause overvoltages. A load switching on or a capacitor bank switching off can causes an undervoltage until voltage regulation equipment on the system can bring the voltage back to within tolerances [8]. The signal of undervoltage is shown in Figure 2.5.

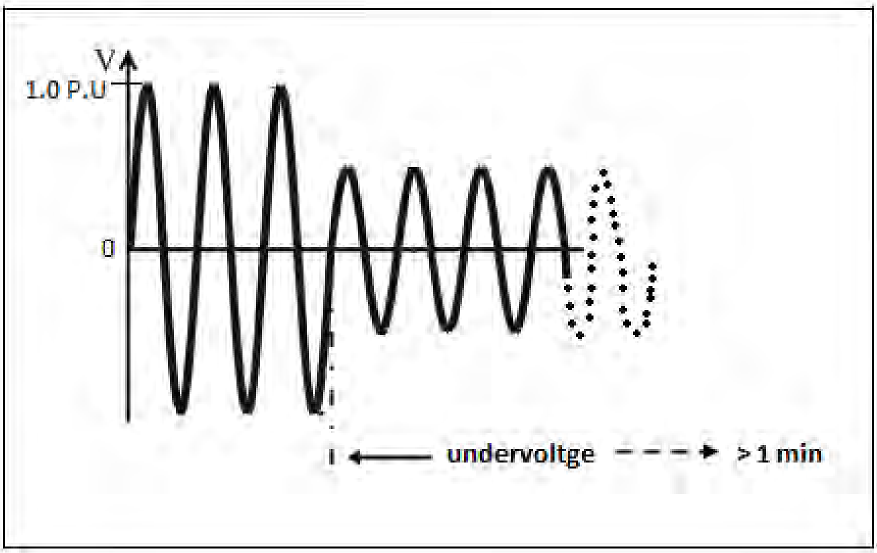

Figure 2.5: Undervoltage signal

2.2.5 Overvoltage

An overvoltage is an increase by ten percent of voltage magnitude from nominal for a duration longer than one minute. Overvoltage usually due to energizing a capacitor bank or switching off a large load [8]. The overvoltage result because either the system is too weak for the desired voltage regulation or voltage controls are inadequate [8]. Incorrect tap settings on transformers can also result in system overvoltage [8]. The example of overvoltage signal is shown in Figure 2.6.

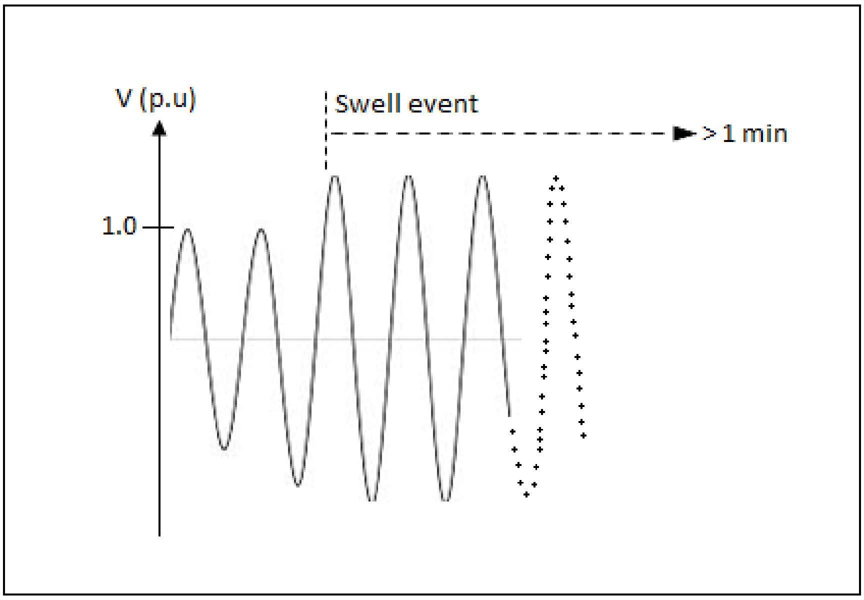

Figure 2.6: Overvoltage signal

2.3 Power Quality Costs Evaluation

Any organizations that related to power quality problem while handling their electrical power systems will face the increment of their costs. During disturbances in power quality, costs can be divided into:

a) Direct costs, which are the costs that relate to the disturbances directly. Salary costs, restart costs, loss of raw materials, damage in equipment and loss of productions are all included in direct costs. Sometimes, during disturbances may be it will not imply production stoppage but other costs may relate to the events like reduction of equipment life and reduction of equipment efficiency [9].

b) Indirect costs. These costs are hardly to evaluate but by taking a situation, a company may not be able to accomplish the delivery on the deadlines due to power quality interruptions. It will be even difficult situation when the company will lose future orders. So that, the investments to prevent power quality problems can be considered as indirect costs [9].

2.4 Costs of Momentary PQ Interruption

Interruptions in power quality will create a huge impact on facilities even just momentary. The costs presented are different for different customers and they are without major investments. The values are based on Electrotek Concept and publish service with individual studies [10]. Table 2.3 below summarizes costs that consumers will face during momentary interruptions [11].

Table 2.3: Typical costs of momentary interruptions [11]

	Cost of momentary interruptions ($/kW demand)	
	Minimum	**Maximum**
Industrial		
Automobile manufacturing	5.0	7.5
Rubber and plastics	3.0	4.5
Textile	2.0	4.0
Paper	1.5	2.5
Printing (newspapers)	1.0	2.0
Petrochemical	3.0	5.0
Metal fabrication	2.0	4.0
Glass	4.0	6.0
Mining	2.0	4.0
Food processing	3.0	5.0
Pharmaceutical	5.0	50.0
Electronics	8.0	12.0
Semiconductor manufacturing	20.0	60.0

2.5 PQ Classification Technique

During PQ interruptions, current or voltage waveforms are recorded in order to determine type of PQ. The waveforms are continuously recorded by using power monitoring instruments where digitized time series of sampled data will generate. Based on previous researchers, discrete Fourier transform (DFT), wavelet transform (WT) and analysis of root-mean-square (RMS) of voltage are the common ways in accessing and monitoring the recorded data. DFT is good to apply for periodic signals but it will not tracks transient signal due to the limitation that it must performed in a window of a fixed length [12]. Meanwhile, WT is a technique to construct a string of time-frequency representations of a signal and the representations are in different solutions which means it is more suitable in identifying details of localized transients. However, sampling window of a certain length is required for WT to perform integral calculations, which increases the computational burden and impairs its attraction. Apart from that, time domain which is essential for the analysis of some particular distorted portion of power system signals is not capable by using WT [13]. The analysis of RMS value of voltage is a good approached but by detecting RMS voltage only is not enough to recognize and classify PQ events due to frequency also changes during interruptions [13]. In this project, PQ classification are rely on the shape information of a power system signal. Compare to the above techniques, analysing the signal data by using phase space technique (used in this project) is more capable in classifying PQ events [14]. Refer to Table 2.1, TNB has stated that voltage magnitude (voltage) and typical durations (frequency) are the two main items in classifying PQ. So that, by monitoring voltage and frequency through phase space technique is enough to classify PQ events in this project.

2.6 Graphical User Interface (GUI)

A graphical user interface (GUI) is a graphical display in one or more windows that enable a user to perform interactive tasks. The development of GUI software applications has made a good improvement in programming field where the difficulty of remembering syntax and semantic has been eliminated by providing the guidance of menu-based interactive properties it delivers [15]. A task can be completed by just create a script and type the commands at the command line of GUI. The components in user interface including menus, toolbars, push buttons, radio buttons, list boxes, and sliders as shown in Appendix A.

MATLAB is one of the software that provide GUI for user to perform any type of read and write data files, communicate with other user interface and display data as table or as plot [16] which means that it is applicable to test the voltage signal by displaying the desired output through table or plot.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the development of the proposed power quality classification technique based on phase space feature extraction. Apart from that, development of will be discussed further in this chapter.

3.2 Phase Space Technique

A dynamical system normally described by a state space where each orthogonal coordinate represents the variable needed to clarify the state of a system [17]. So that all the possible states of the dynamical system are represented in the state space and each possible state corresponds to a unique point. Normally, it is impossible to measure the variables of a dynamical system but Takens in [18] has proved that it can be reconstructed from a time series of a collection of the states using the embedding theorem.

The solution of this equation $\boldsymbol{s} \in \mathfrak{R}^{\boldsymbol{D}}$, is a state in the corresponding phase space where $\mathfrak{R}$ indicates the Euclidean space. The measured function $\boldsymbol{x} = h(\boldsymbol{s})$ transform a collection of $\mathbf{s}$ state to a scalar time series. The 'delay' of the time series is denoted by a positive number of $\boldsymbol{\tau}$. The evolutions of the state $\boldsymbol{s}$ at time $\boldsymbol{i}$ is defined by the function $\boldsymbol{F}_\tau(\boldsymbol{s}_i) = \boldsymbol{s}_{i+\tau}$. So, the embedding $\Phi: \mathfrak{R}^D \rightarrow \mathfrak{R}^{D_E}$ which is called the delay-coordinate is defined as