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Name : **Carolyn Lim Kim Yen**

Course : **4BEKP S2**

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Supervisor : **Nur Hazahsha binti Shamsudin**

PERFORMANCE ANALYSIS OF POWER QUALITY MONITORING SYSTEM

Carolyn Lim Kim Yen

Bachelor of Electrical Engineering (Industrial Power)

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"I hereby declare that I have read through this report entitled "Performance Analysis of Power Quality Monitoring System" and found that it has comply the partial fulfilment for awarding the degree of *Bachelor of Electrical Engineering (Industrial Power)*"

Signature : ....

Supervisor's Name : ....

Date : ....

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CAROLYN LIM KIM YEN

This report is submitted in partial fulfilment of requirement for the degree of Bachelor in Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

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2014

I declare that this report entitled "Performance Analysis of 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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Name : ....

Date : ....

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ABSTRACT

The presence of power quality (PQ) problem in the power supply system can cause malfunction of the modern high technology devices and these faults will bring about immense financial losses in the commercial and industrial sectors. Essentially, there is a need to determine the type of PQ problem that occurred, so that proper actions can be taken to overcome the problem. Most of the PQ instruments available in the market are unable to classify PQ events, thus power quality monitoring system (PQMS) is developed by previous researchers to solve that problem. The flexibility of PQMS has facilitated in identifying PQ problem that is globally experienced in real electrical delivery of power system prominently in distribution. It is suitable for remote measurement of various non-linear loads, as well as instantaneous classification of the PQ problem. The validation of PQMS performance in measurements and PQ detection through numerous laboratory experiments is feasible by using Fluke 43B power quality analyser (PQA) as the reference tool. Five different set-ups with components like three phase induction motor, single phase capacitor run motor and single phase full wave controlled rectifier are constructed for no load test, blocked rotor test, voltage sag and harmonic distortion in single phase and three phase system. The no load and blocked rotor tests data collection inclusive of voltage, current, real power, reactive power, apparent power and power factor has prompted the measurement accuracy assessments. The voltage sag and harmonic distortion are induced for testing the PQMS ability in identifying the signal disturbances. The effectiveness of PQMS is emphasized through the comparisons between the signals obtained and absolute percent error (APE) of the measurements with the results of PQA. In short, the performance of PQMS in signal detection and measurement is verified.

ABSTRAK

Kewujudan masalah kualiti kuasa (PQ) dalam sistem bekalan kuasa boleh menyebabkan kerosakan peranti-peranti modern yang berteknologi tinggi dan kerosakan tersebut akan membawa kerugian yang banyak dalam sektor perdagangan dan perindustrian. Ia adalah penting untuk menentukan jenis masalah PQ supaya tindakan yang sesuai boleh diambil untuk menyelesaikan masalah tersebut. Kebanyakan peralatan PQ yang ada dalam pasaran tidak mampu untuk mengklasifikasikan masalah PQ, oleh itu sistem pemantauan kualiti kuasa (PQMS) telah dicadangkan oleh penyelidik sebelum ini untuk mengatasi kelemahan tersebut. Fleksibiliti PQMS telah memudahkan identifikasi masalah PQ yang dialami secara global dalam penghantaran bekalan kuasa menerusi sistem pengedaran. Ia juga sesuai bagi ukuran jauh untuk pelbagai jenis beban tidak linear serta klasifikasi masalah PQ dengan kadar segera. Pengesahan pretasi PQMS dalam ukuran dan pengesanan masalah PQ melalui pelbagai eksperimen makmal boleh dilaksanakan dengan menggunakan penganalisis kualiti kuasa (PQA) Fluke 43B sebagai rujukan. Lima eksperimen dengan komponen yang berbeza seperti motor tiga fasa, motor kapasitor larian fasa tunggal, dan rektifier gelombang penuh terkawal telah digunakan untuk ujian tanpa beban, ujian pemutar tersekat, pengenduran voltan dan herotan harmonik dalam sistem fasa tunggal dan tiga fasa. Data-data seperti voltan, arus, kuasa sebenar, kuasa reaktif, kuasa ketara dan faktor kuasa yang dikumpul melalui ujian tanpa beban dan ujian pemutar tersekat telah mendorong penilaian ketepatan pengukuran. Di samping itu, pengenduran voltan dan herotan harmonik dalam sistem fasa tunggal dan tiga fasa adalah bertujuan untuk menguji keupayaan PQMS dalam mengenal pasti gangguan isyarat. Keberkesanan PQMS telah ditekankan melalui perbandingan antara isyarat diperolehi dan peratusan ralat mutlak (APE) dalam ukuran dengan keputusan yang diperoleh PQA. Kesimpulannya, prestasi PQMS dalam pengesanan isyarat dan pengukuran telah disahkan.

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AC	-	Alternating current
ADALINE	-	Adaptive Linear Neural Network
ADC	-	Analogue to digital
APE	-	Absolute percent error
ASD	-	Adjustable speed drives
AWG	-	Arbitrary waveform generator
DAQ	-	Data acquisition
DC	-	Direct current
EAF	-	Electric arc furnace
EMI	-	Electromagnetic interference
FFT	-	Fast Fourier transform
FKE	-	Faculty of Electrical Engineering
GUI	-	Graphical user interface
HOS	-	Higher-order statistics
I/O	-	Input/output
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronics Engineers
IGBT	-	Insulated gate bipolar transistor

IPC	-	Industrial Power Corruptor
NI	-	National Instrument
PC	-	Personal computer
PLL	-	Phase-locked-loop
PQ	-	Power quality
PQA	-	Power quality analyser
PQMS	-	Power quality monitoring system
RLC	-	Resistive, inductive and capacitive
rms	-	Root mean square
SCR	-	Silicon controlled rectifier
SRPA	-	Smart recording power analyser
STFT	-	Short time Fourier transform
TFR	-	Time frequency representation
THD	-	Total harmonic distortion
UPS	-	Uninterruptable power supply
USB	-	Universal Serial Bus
VI	-	Virtual instrument

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Power quality (PQ) is a set of parameters that delineate the properties of power supplied to the users in terms of supply continuity and voltage characteristics during typical operating conditions [1]. The deviations of voltage, current or frequency from its constant magnitude and ideal sinusoidal waveform can induce failure in any sensitive electric equipment. There are six categories of common PQ problems, namely voltage fluctuation, harmonic distortion, power frequency variation, undervoltage or overvoltage, voltage sag or swell, and transients. These issues have always been present in the power supply system, but they are not in the limelight until recently due to the intensified usage of power electronic gadgets. Non-linear loads which have become a prominent part in the industrial and commercial power systems tempt to draw non-sinusoidal currents from the supply, thus inducing voltage distortion and affecting the power factor [2]. Since the control system equipped in the devices can be malfunctioned due to the varying supply conditions, this justify that the modern electronic devices in electrical system are more sensitive to PQ issues than those from the olden days. For instance, the proper operation of high technology electricity dependent devices and instruments depends on the voltage quality supplied to them.

This project intends to analyse the performance of Power Quality Monitoring System (PQMS) and determine its functionality in the practical environment. Besides measuring voltage, current, real power, reactive power, apparent power and power factor, PQMS [3] is also capable in classifying the PQ problem being measured. Hence, users can identify the PQ problem instantly without struggling to pinpoint the problem from the recorded signal. For example, if sag occurred in the system during the monitoring, the word “sag” will be displayed in the graphical user interface. Another feature of this PQMS is data recording. As the name “Real Time Power Quality Monitoring System” implies, it can monitor the power system in real time, where the changes occurred in the power system can be recorded and saved as a text file in the PQMS for further analysis. The PQMS is proposed to serve as an alternative to the pricy PQ measuring instruments available in the market, so it is necessary to compare the performance and capability of the PQMS with those equipment accordingly.

Theoretically, PQMS is capable of measuring and detecting the PQ problems. Hence, laboratory testing is carried out for the system performance verification. There are two methods for producing PQ problem signals, i.e. signal generator and experimental set up [4]. Although an ideal signal waveform can be generated from signal generator, it does not mean that particular signal will also occurred in the real world. However, it is a good choice if one does not have access to the vast choices of equipment to set up an experiment. The downside of using experimental set up is the condition of the equipment. For instance, after running for a long time, a motor will be heated and thus affecting the output. The efficiency of a piece of worn out equipment is also low compared to the new ones. Despite the drawbacks disclosed earlier, the output from an experimental set up represents best on the phenomena that could happen in a real world situation.

1.2 Problem Statement

PQMS has been tested through simulation by the previous researchers [3]. The simulation results showed that the system can measure and classify PQ problems. Although the system has passed the simulation testing, but it does not prove that it will be able to give similar performance in the real world situation measurements and classification. The performance of the developed monitoring system needs to be determined so that PQMS can serve as one of the alternative instruments used for PQ monitoring in practical environment.

1.3 Objectives

This project primarily focused on achieving the following objectives:

i) To test PQMS aptitude in power system measurements through voltage-varying experimental set ups.

ii) To generate voltage sag and harmonic signals through laboratory experiments for verifying PQMS ability in classifying PQ problem.

iii) To analyse the performance of the PQMS in reference with Fluke 43B PQA.

1.4 Scope

In order to validate the performance of PQMS in terms of measurements and PQ disturbances classification, various experiments are conducted in the laboratories at Faculty of Electrical Engineering (FKE), UTeM and all the experimental outcomes are compared with the data logged by Fluke 43B PQA. Three phase squirrel cage induction motor no load test and blocked rotor test are chosen for testing the PQMS accuracy in measuring six types of power system parameters which include voltage, current, real power, reactive power, apparent power and power factors. There are two types of PQ problem in single phase and three phase systems concerned in this project, for instance voltage sag and harmonic distortion.

1.5 Project Outcome

Five different laboratory experiments are conducted to determine the accuracy of PQMS in taking measurements as well as the efficiency in identifying the PQ problems. Fluke 43B PQA is chosen as the reference instrument because it can perform all the measurements that are required in this project. Through the no load test and blocked rotor test, the PQMS accuracy in measuring the distinctive power system parameters such as voltage, current, real power, reactive power, apparent power and power factor has been ascertained with the APE calculated from the results obtained by PQA and PQMS. The mean APE from each parameter further justified the performance of PQMS.

Voltage sag signals in single phase system are generated with two different loads, for instance six capacitor run motors and four capacitor run motors with RLC load. These two types of load managed to cause a voltage drop which is more than 10% of the nominal 240V, thus satisfying the IEEE definition for sag. When the three phase motor is started up, the phase to phase measurement at the supply also presented similar trend. During the drop in voltage due to motor starting, PQMS has successfully classified the voltage drop as “sag”. Fluke 43B PQA does not have the function to categorize the voltage drop as “sag”, but through calculation and analysis, the signals have confirmed to demonstrate voltage sag during the motor starting.

Other than voltage sag, harmonic distortion is another PQ event concerned. The harmonic voltage and current signals from the single phase full wave controlled rectifier and three phase induction motor are logged with PQA and PQMS. The representation of total harmonic distortion (THD) is different for the two instruments. Although THD is displayed as number and line graph in PQA and PQMS respectively, but the value shown by the instruments are similar. Only the signal distortion in full wave controlled rectifier is categorized as “Harmonic”. Although there are certain percentage of THD present in the three phase induction motor signals, but they are not considered by PQMS as harmonics.