OPTIMIZATION OF POWER QUALITY MONITORS IN TRANSMISSION SYSTEM NETWORK

ABUBAKAR KABIR ALIYU

UNIVERSITI TEKNOLOGI MALAYSIA

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ABUBAKAR KABIR ALIYU

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To my beloved father Alhaji Aliyu Abubakar Mashi,

My mother Hajiya Habiba Aminu Mashi,

And to the entire members of my family

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ABSTRACT

Power quality disturbances cause a great financial loss in the order of billions worldwide due to population growth, more sensitive devices and the significant usage of electricity. The power quality monitoring system aimed at determining the causes and the classification of power quality disturbances so that proper action can be taken. Among all power disturbances, voltage sags are considered as the most frequent and severe type of disturbances that lead to loss of operation of equipment's. The power quality monitoring system is the first to consider in power quality assessment and mitigation so as to get a reliable and efficient power supply. Installing power quality monitors (PQM) in every component of the power system network is not feasible due to economic reasons and its need to be minimized. And then how to get the optimal number and locations of power quality monitors while maintaining system observability becomes an important problem. The aim of this research is to find the optimal number and the best location of power quality monitors in the system network. The IEEE 14 bus test system was modelled and analyzed using POWERWORLD software so as to obtain fault voltage and monitor reach area matrixes considering balanced and unbalanced faults in the system. The optimization formulation problem is also formed and solved using a MATLAB toolbox of an integer programming algorithm and sag occurrence value is used to find the best placement position. Finally, this research end with the comparison with the MATLAB toolbox of genetic algorithm. Thus, both the IP and GA techniques give the same optimal number for a different set threshold value. However, for a threshold value of 0.9 p.u ,the optimal number of PQM is 1 for each of the simulated fault type in the system and different number of PQM for a threshold value of 0.55p.u and o.2p.u depending on the sensitivity of voltage sag occurrences of each of the simulated fault type in the system.

ABSTRAK

Gangguan kualiti kuasa menyebabkan kerugian kewangan yang besar dalam perintah-bilion di seluruh dunia disebabkan oleh pertumbuhan penduduk, peranti lebih sensitif dan penggunaan yang ketara elektrik. Sistem pemantauan kualiti kuasa bertujuan untuk menentukan sebab-sebab dan pengkelasan gangguan kualiti kuasa supaya tindakan sewajarnya dapat diambil. Di antara semua gangguan kuasa, sags voltan adalah dianggap jenis yang paling kerap dan teruk gangguan yang membawa kepada kehilangan operasi peralatan ini. Sistem pemantauan kualiti kuasa adalah yang pertama yang perlu dipertimbangkan dalam penilaian kualiti kuasa dan pengurangan bagi mendapatkan bekalan kuasa yang boleh dipercayai dan cekap. Memasang monitor kualiti kuasa (PQM) dalam setiap komponen rangkaian sistem kuasa tidak boleh dilaksanakan kerana sebab-sebab ekonomi dan keperluan untuk dikurangkan. Dan kemudian bagaimana untuk mendapatkan nombor yang optimum dan lokasi monitor kualiti kuasa di samping mengekalkan sistem keteramatan menjadi satu masalah yang penting. Tujuan kajian ini adalah untuk mencari bilangan optimum dan lokasi yang terbaik monitor kualiti kuasa dalam rangkaian sistem. IEEE 14 bas sistem ujian telah dimodelkan dan dianalisis menggunakan perisian POWERWORLD untuk memperolehi voltan kesalahan dan memantau matrixes kawasan jangkauan memandangkan kesalahan yang seimbang dan tidak seimbang di dalam sistem. Masalah penggubalan pengoptimuman juga dibentuk dan diselesaikan dengan menggunakan toolbox MATLAB sesuatu pengaturcaraan integer algoritma dan mengendur nilai berlakunya digunakan untuk mencari kedudukan peletakan terbaik. Akhir sekali, kajian ini berakhir dengan perbandingan dengan toolbox MATLAB algoritma genetik. Oleh itu, kedua-dua IP dan teknik GA memberikan nombor optimum yang sama untuk nilai ambang satu set yang berbeza. Walau bagaimanapun, bagi nilai ambang 0.9 pu, bilangan optimum PQM adalah 1 bagi setiap jenis simulasi kesalahan dalam sistem dan nombor berbeza PQM untuk nilai ambang 0.55pu dan o.2p.u bergantung kepada sensitiviti kejadian mengendur voltan setiap jenis kesalahan simulasi di dalam sistem.

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LIST OF ABBREVATIONS

PQ	-	Power quality
PQMs	-	Power quality monitors
MRA	-	Monitor reach area
MP	-	Monitor position
IP	-	Integer programming
GA	-	Genetic algorithm
SLGF	-	Single line to ground fault
LLF	-	Line to line fault
DLGF	-	Double line to ground fault
SOV	-	Sag occurrence value
RMS	-	Root mean square
p.u	-	Per unit
IEC	-	International electro-technical commission
IEEE	-	Institute of electrical and electronics engineers
TMRA	-	Topological monitor reach area
3PF	-	Three phase fault

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Traditionally the industrial electric power model has been controlled by large utilities over the years that are monopolistic in nature comprises of generation, transmission and distribution of electric power within its vicinity of the operation. Such utilities have functioned as the only electricity provider in the country and the consumers usually accept the percentage level of delivered power quality. The price is always set by the regulatory body and often does not involve in the quality of the power delivered. [1]

The importance of power quality has tremendously increased due to several points of views. Firstly, change in the nature of our electrical loads, i.e. the load characteristic has become more complex due to high use of electronics equipment's and sensitive loads which result to power line deviation (variation of voltage and current waveform). With the advancement in technology, there are a lot of sensitive equipment's such as microprocessor, computer, variable speed drives, welders, arc furnace etc. [2]

Secondly, deregulated market in the power sector has led to an important structural change in the utility industry. Customers have the choice to purchase electricity from different utilities depending on the utilities that deliver electric power at least cost, acceptable reliability and of good quality that meet their load demand. [1]

Thirdly, Population i.e. many people nowadays are wholly depends on electricity in their daily life that is reliable and efficient. Consumers are now aware of their right and demand low price of electricity of high reliability, efficiency and good quality. [3]

Power quality will be tackled with an important consideration upon which demand utilities convey reliable and good quality of electrical power to the customers. In all the power quality disturbances, voltage sags are the most frequent disturbances that have a great impact on sensitive loads. [1] According to IEEE standard 1159-1995 definition, voltage sag is the reduction of voltage in its R.M.S value between 0.1p.u and 0.9p.u for a duration between half a cycle and less than 1 minutes. [2] Due to high economic losses of voltage sags problems which are malfunctioning or failure of sensitive equipment in industries and some sensitive equipment's in residential. Monitoring of the system is of great importance so as to assess and mitigate such disturbances. [4]

The Power quality monitoring system is the first to consider for a good and reliable power. It is important to know the fault location and the type of electrical disturbances in order to assess and mitigate so as to have a good power quality

Power quality monitoring systems program determines the methods for collecting data, the type of measurement equipment's, etc. There are various electrical power disturbances such as sag, swell, harmonics, transient, flicker etc. the simplest way to classify a power quality monitoring system is based on;

i. System monitoring: its objectives is to determine the quality of power and the behaviour of electrical system globally. i.e. to check the voltage in all buses are within the acceptable range of the institutions (either IEC or IEE and so on), so as to avoid malfunction or failure.

ii. Local monitoring: its objectives is to determine the quality of power that is delivered to a single customer. It is useful to identify if the utility is supplying power with the level of quality agreed upon, identifying the source of electrical disturbance, whether it is internal or external so as to improve the power quality services. [2]

In conventional methods, power quality monitors are installed at every component of the power system network. Though it is uneconomical and it creates a lot of redundant data. [5]

1.2 Problem Statement

The Power quality monitoring system is the first to consider in power quality assessments and mitigation so as to get reliable and efficient power supply. Ideally, power quality monitors are installed at every component of the power system network. Due to uneconomical to install power quality monitors in every component of the power system network and the generation of a lot of redundant data. Power quality monitor cost about RM 40000 each, which is of very high cost to be installed in every power system component. Many researchers are working on how to minimize the number of power quality monitors on the power system network and to reduce the amount of redundant data generated by using various optimization techniques and a suitable placement method. So as to find the techniques and placement methods that are more effective and reliable. That is minimizing the number of power quality monitors and maximizing efficiency are the main issues.

1.3 Objectives

As power quality monitoring is the first to consider in PQ assessments and mitigation, the objectives are concentrated on optimizing the PQMs so as the system to be cost effective. Though considering the observability of the system as every event that lead to voltage sags is captured. Perhaps for the optimization to be fulfilled certain objectives need to be defined.

i. To **obtain** the voltage sags magnitude due to balanced and unbalanced fault at every component of the network system.

ii. To **determine** a minimum number of power quality monitors in the network system (with efficiency considering).

iii. To **find** the best placement positions of the power quality monitors.

1.4 Scope of Study

The project focuses on voltage sags/dips based on balanced (three phase) fault and unbalanced (single line to ground, double line to ground and line to line) fault of the system. IEEE 14 bus transmission system is utilized as a case study for this project. Modelling and simulation of the system using SIMULINK MATLAB software to show the effect of voltage magnitude due to all types. Also, Modelling, simulation and analyzing the system network using POWERWORLD simulator software for the fault analysis considering all types of faults. The fault voltage magnitude and monitor reach area matrices were obtained based on the fault analysis of different types of fault. Then, 0-1 integer programming optimization and genetic algorithm toolbox from the MATLAB environment were used for the optimization of the problem formulated.

1.5 Thesis Outline

The structure of this thesis is divided into five chapters, which are arranged as follows:

Chapter 1 presents an introduction of the study followed by the problem statements, objectives of the study and scope of the study.

Chapter 2 provide an extensive review of theories of the study which comprises of power quality, power quality disturbance, power quality monitoring system, the basic of voltage sag i.e. fault analysis, optimization techniques based on IP and GA and finally review of the past research work.

Chapter 3 presents an in-depth explanation of the tools used for the fault analysis which is POWERWORLD simulator, MATLAB toolbox both IP and GA for the optimization. The concept of monitor area concept and optimization problem formulation and their expression are discussed extensively. Also mathematical equations for voltage sag assessments are discussed well.

Chapter 4 presents the results and discussion of the study. The IEEE 14 bus system was modelled and simulated using SIMULINK MATLAB for both balanced and unbalanced fault and the waveforms are shown and explained. The results optimal number using IP and GA optimization techniques and best placement position using sag occurrence value and it ended with an extensive discussion of the results.

Chapter 5 presents the conclusion and recommends some further work for improving this study.

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