VOLTAGE SAGS MITIGATION TECHNIQUES ANALYSIS

NORSHAFINASH BINTI SAUDIN

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Electrical – Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2007

To my beloved husband

ACKNOWLEDGEMENT

I would like to express my gratitude to Allah S.W.T. for giving me the opportunity to complete this Master's Project. I am deeply indebted to individuals who, directly or indirectly, are responsible for this project.

I am most grateful to the most kindheartedness supervisor Dr Ahmad Safawi bin Mokhtar for his guidance in this project and to panel of seminar presentation, PM. Dr. Mohd Wazir bin Mustafa and PM. Md. Shah Majid, with their superior guidance, information and ideas for this project become abundance.

My admiration falls upon En. Saudin bin Mat, my father, and especially to my mother, Pn. Siah binti Taharin for them to bear with me my absence in the family. Your encouragement, pray and support are very much appreciated.

I would also like to express my sincere thanks to my entire friend for their support and ideas during the development of the project.

And last but not the least, to my husband, thanks.

ABSTRACT

For some decades, power quality did not cause any problem, because it had no effect on most of the loads connected to the electric distribution system. When an induction motor is subjected to voltage sag, the motor still operates but with a lower output until the sag ends. With the increased use of sophisticated electronics, high efficiency variable speed drive, and power electronic controller, power quality has become an increasing concern to utilities and customers. Voltage sags is the most common type of power quality disturbance in the distribution system. It can be caused by fault in the electrical network or by the starting of a large induction motor. Although the electric utilities have made a substantial amount of investment to improve the reliability of the network, they cannot control the external factor that causes the fault, such as lightning or accumulation of salt at a transmission tower located near to sea. This project intends to investigate mitigation technique that is suitable for different type of voltage sags source with different type of loads. The simulation will be using PSCAD/EMTDC software. The mitigation techniques that will be studied are such as Dynamic Voltage Restorer (DVR), Distribution Static Compensator (DSTATCOM) and Solid State Transfer Switch (SSTS). All the mitigation techniques will be tested on different type of faults. The analysis will focus on the effectiveness of these techniques in mitigating the voltage sags. The study will also investigate the effects of using the techniques to phase shift. At the end of the project it is expected that a few suggestions can be made on the suitability of the techniques.

ABSTRAK

Beberapa dekad yang lalu, kualiti kuasa tidak menjadi permasalahan kerana ia tidak memberi kesan yang sangat nyata kepada beban yang bersambung dengan sistem pengagihan. Apabila motor aruhan mengalami voltan lendut, motor tersebut masih berfungsi tetapi dengan keluaran yang lebih rendah sehingga kejatuhan voltan tamat. Walau bagaimanapun, dengan peningkatan penggunaan peralatan elektronik yang maju, pemacu pelbagai halaju berkecekapan tinggi, dan pengawal elektronik kuasa, kualiti kuasa mula menjadi perhatian kepada utiliti dan pelanggan. Di mana, voltan lendut adalah gangguan kualiti kuasa yang seringkali terjadi terhadap sistem pengagihan yang disebabkan oleh kerosakan pada rangkaian elektrik dan pemulaan yang besar untuk motor aruhan. Walaupun utiliti telah membuat pelaburan untuk memperbaiki keboleharapan rangkaian, faktor luaran yang menyebabkan kerosakan masih tidak dapat dikawal, contohnya kilat dan pengumpulan garam pada menara penghantaraan yang terletak berhampiran dengan laut. Oleh itu, projek ini bertujuan mengkaji kesesuaian teknik mitigasi untuk pelbagai punca voltan lendut pada beban yang berbeza di mana perisian PSCAD/EMTDC digunakan sebagai bantuan untuk simulasi. Teknik - teknik mitigasi yang dikaji adalah seperti *Dynamic Voltage Restorer (DVR)*, *Distribution Static Compensator (DSTATCOM),* dan *Solid State Transfer Switch (SSTS).* Teknik - teknik ini akan diuji dengan pelbagai kerosakan yang menyebabkan voltan lendut. Tumpuan akan diberikan kepada keberkesanan teknik-teknik tersebut untuk mengatasi voltan lendut dan kesannya terhadap anjakan fasa. Di akhir projek ini, beberapa cadangan akan diutarakan berkenaan kesesuaian teknik - teknik tersebut digunakan untuk mengatasai voltan lendut.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CBEMA	-	Computer Business Equipment Manufacturers Association
DSTATCOM	-	Distribution Static Compensator
DVR	-	Dynamic Voltage Restorer
EMTDC	-	Electromagnetic Transient Program with DC Analysis
ERM	-	Electronic Restart Modules
Hz	-	Hertz
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronics Engineers
ITIC	-	Information Technology Industry Council
kV	-	kilovolt
MVA	-	megavolt ampere
MVAR	-	mega volt amps reactive
MW	-	megawatt
p.u.	-	per unit
PCC	-	point of common coupling
PSCAD	-	Power System Aided Design
PWM	-	Pulse Width Modulation
RMS	-	root mean square
SEMI	-	Semiconductor Equipment and Materials International
SSTS	-	Solid State Transfer Switch
TNB	-	Tenaga Nasional Berhad
TRV	-	transient recovery voltage

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Introduction

Both electric utilities and end users of electrical power are becoming increasingly concerned about the quality of electric power. The term *power quality* has become one of the most prolific buzzword in the power industry since the late 1980s [1]. The issue in electricity power sector delivery is not confined to only energy efficiency and environment but more importantly on quality and continuity of supply or power quality and supply quality. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. Power quality may also be defined as the degree to which both the utilization and delivery of electric power affects the performance of electrical equipment [2]. From a customer perspective, a power quality problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or disoperation of customer of equipment [3].

Power quality problems concerning frequency deviation are the presence of harmonics and other departures from the intended frequency of the alternating supply voltage. On the other hand, power quality problems concerning voltage magnitude deviations can be in the form of voltage fluctuations, especially those causing flicker. Other voltage problems are the voltage sags, short interruptions and transient over voltages. Transient over voltage has some of the characteristics of high-frequency phenomena. In a three-phase system unbalanced voltages also is a power quality problem [2]. Among them, two power quality problems have been identified to be of major concern to the customers are voltage sags and harmonics, but this project will be focusing on voltage sags.

Figures 1.1 describe the demarcation of the various power quality issues defined by IEEE Std. 1159-1995. [4]

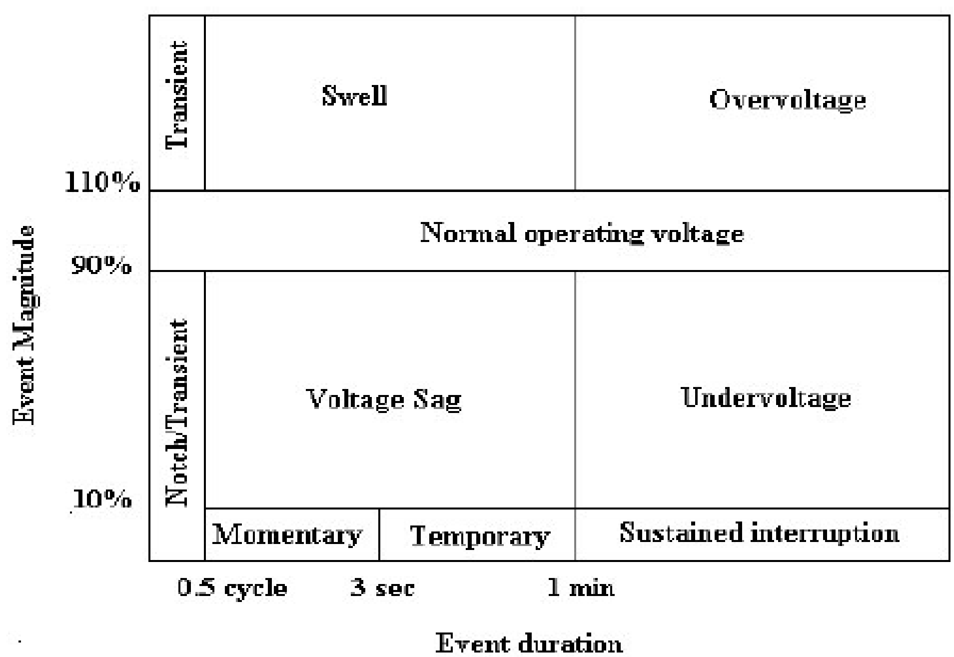

Figure 1.1 Demarcation of the various power quality issues defined by IEEE Std. 1159-1995[4]

Three factors that are driving interest and serious concerns in power quality are [1]:

i. Increased load sensitivity and production automation. The focus on power quality is therefore more of voltage quality as the momentary drop in voltage disrupts automated manufacturing processes.
ii. Automation and efficiency relies on digital components which requires dc supply. As public utilities supply ac power, dc power supplies powered by ac are needed by the dc loads.
iii. As more dc power supply are needed the converters that convert ac to dc cause harmonics to be injected into the system and hence reduce wave form quality

1.2 Problem Statement

With the increased use of sophisticated electronics, high efficiency variable speed drive, and power electronic controller, power quality has become an increasing concern to utilities and customers. Voltage sags is the most common type of power quality disturbance in the distribution system. It can be caused by fault in the electrical network or by the starting of a large induction motor. Although the electric utilities have made a substantial amount of investment to improve the reliability of the network, they cannot control the external factor that causes the fault, such as lightning or accumulation of salt at a transmission tower located near to sea.

Meanwhile during short circuits, bus voltages throughout the supply network are depressed, severities of which are dependent of the distance from each bus to point where the short circuit occurs. After clearance of the fault by the protective system the voltages return to their new steady state values. Part of the circuit that is cleared will suffer supply disruption or blackout. Thus in general a short circuit will cause voltage sags throughout the system but cause blackout to a small portion of the network [1].

A comprehensive study on the cost of losses due to power quality problem has not been carried out yet. However, it has been reported that a petrochemical based industries customer in the Tenaga Nasional Berhad, Malaysia system can lose up to RM164,000 (US$43,000) per incident related to power quality problem due to voltage sag. Another semiconductor-based industry in the Klang Valley has estimated the loss of RM5million for the year 2000. Other types of industries such the cement and garment industries in Malaysia have also reported huge losses due power quality problems. One cement plant has reported an average loss of RM300, 000 per incident [2].

Cause of Interruption	No. of Interruptions	
	1999	2000
Natural Disasters (wind, storm, flood, land slides etc.)	38.9%	37.6%
Caused by third parties	7.1%	8.3%
Poor Workmanship	14.4%	12.8%
Over Loading	11.6%	10.5%
Wrong Operation/Settings	0.3%	0.2%
Equipment failure	13.9%	17.7%
Miscellaneous	13.8%	12.9%
Total	37,761	48,566

Table 1.1 Cause of TNB network disruption [2]

In general, voltage sags can causes:

i. Motor load to stall/stop
ii. Digital devices to reset causing loss of data
iii. Equipment damage and/or failure
iv. Materials Spoilage
v. Lost production due to downtime
vi. Additional costs
vii. Product reworks
viii. Product quality impacts
ix. Impacts on customer relations such as late delivery and lost of sales
x. Cost of investigations into problem

Therefore, this project intends to investigate mitigation technique that is suitable for different type of voltage sags source with different type of loads.

1.3 Project Objectives

The objectives of this project are:

i. To investigate suitable mitigation techniques for different type of voltage sags source that connected to linear and non-linear load.
ii. To simulate and analyze the techniques using PSCAD/EMTDC software.
iii. To observe the effect on the characteristic of voltage sag such as the magnitude and phase shift for each techniques.
iv. To make a few suggestions on the suitability of such techniques used for both type of loads.

1.4 Project Scope

The scopes for the project are:

i. Mitigation techniques that will be studied
   a. Dynamic Voltage Restorer (DVR),
   b. Distribution Static Compensator (D-STATCOM),
   c. Solid State Transfers Switch (SSTS), and
ii. All techniques will be tested on different type of loads.
iii. Analysis will focus on effectiveness of each techniques in mitigating the voltage sags