

VOLTAGE SAG ANALYSIS AND DETERMINATION OF THE SOURCE OF
DISTURBANCE IN INDUSTRIAL SECTOR

FARALYNA AISYAH BINTI ABDUL RASID

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

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2014

To my beloved mother and father

ACKNOWLEDGEMENT

In the name of ALLAH S.W.T., the Most Compassionate, the Most Merciful.

I am indebted to so many people for the completed the final year project report. My first gratitude goes to my supervisor, Dr. Dalila binti Mat Said for her kind introduction to how this Master project report will be, also for her support, guidance, encouragement, critics and friendship throughout the year. Without her continuous support, this thesis will not be able to be the same as presented here.

I also indebted to postgraduate friends, classmate and everyone for their kind word of encouragement and professional advice on many of the chapter of this final Master project report. A special thanks to the librarians at Universiti Teknologi Malaysia (UTM) and the National Library of Malaysia for their assistance in supplying relevant literature.

Lastly, my special gratitude goes to a group of special people who kindness and emotional support we have often taken for granted: our parents, siblings and the whole clan whose overflowing love we have greatly benefited from. Thank you.

ABSTRACT

Power quality analysis has become one of the main objective of study in electric power systems. Voltage sag is a phenomena where voltage decrease to 90% to 10% of the rated voltage, with a typical duration of 0.5 to 30 cycle. The purpose of this study is to analyze the voltage sag events in order to identify the source and the cause of voltage sag. Voltage sag is a power quality problem that seldom occurred, but once it occur, it will cause severe problems, such as industrial processes malfunction, producing great economic losses and reduce the power quality. To improve power quality, it is important to identify the source of disturbance. The analysis performed by using the data of voltage sag event shows that the major source of the voltage sag is because of the external factor, while the cause of the voltage sag are mainly by the short circuit. The mitigation technique shall be propose along the analysis, because the effect of the voltage sag can be reduce when applying the mitigation technique such as by using an Uninterruptable Power Supply (UPS) and Voltage Stabilizer at both utility and customer side.

ABSTRAK

Analisis kualiti kuasa menjadi salah satu objektif penting dalam pembelajaran sistem kuasa elektrik.. Voltan lendut ialah suatu fenomena di mana nilai voltan jatuh kepada 90% sehingga 10% daripada nilai sebenar voltan, dengan masa biasa berlaku voltan lendut adalah dalam tempoh 0.5 sehingga 30 kitaran. Tujuan kajian ini dilaksanakan adalah untuk mengkaji tentang aktiviti voltan lendut, supaya dapat mengenal pasti bahan penyebab dan punca berlakunya voltan lendut tersebut. Voltan lendut adalah masalah kualiti kuasa yang jarang berlaku, tetapi, apabila ianya berlaku, ia akan menyebabkan beberapa masalah, seperti operasi di industri tidak dapat berfungsi, ini menyebabkan kerugian besar ekonomi dan mengurangkan kualiti kuasa. Untuk memperbaiki masalah kualiti kuasa, adalah sangat penting untuk mengenalpasti penyebab kepada gangguan tersebut. Analisis yang dilaksanakan dengan menggunakan data voltan lendut menunjukkan bahawa faktor luaran merupakan penyebab utama kepada gangguan kuasa, manakala punca utama berlakunya voltan lendut ini adalah kerana litar pintas. Kaedah pencegahan voltan lendut perlu diperkenalkan seiring dengan analisis yang dilakukan, kerana kesan daripada aktiviti voltan lendut dapat dikurangkan apabila teknik pemuliharaan seperti penggunaan Uninterruptable Voltage Supply (UPS system) dan penstabil voltan (Voltage Stabilizer) digunakan di kedua-dua bahagian iaitu pada pembekal kuasa dan pengguna kuasa.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Project background	4
	1.3 Problem Statement	5
	1.4 Objectives	6
	1.5 Scope of Work/Limitation	6
2	LITERATURE REVIEW	7
	2.1 Introduction	7
	2.2 Voltage tolerance curve	8
	2.2.1 ITIC curve	8
	2.2.2 CBEMA curve	10
	2.2.3 SEMI F47	11
	2.2.4 IEC 61000-4-34	12
	2.3 Common cause of the voltage sags	14

	2.3.1 Due to the short circuit	14
	2.3.2 Due to the transformer energizing	15
	2.3.3 Due to the induction motor starting	15
	2.4 Summary of the past works	16
	2.5 Losses cause by voltage sag problem	17
	2.5.1 Lost in term of cost (RM)	18
3	METHODOLOGY	20
	3.1 Introduction	20
	3.2 Flow of methodology	21
	3.2.1 Literature review/background of study	21
	3.2.2 Data collection	22
	3.2.3 Data analysis	22
	3.3 Cause of voltage sag : Detection Method	25
4	RESULTS	28
	4.1 Introduction	28
	4.1.1 External factor and internal factor	29
	4.2 Voltage sag analysis	30
	4.2.1 Company A	30
	4.2.1.1 Event number : 25	31
	4.2.1.2 Event number : 28	33
	4.2.1.3 Event number : 31	35
	4.2.2 Company B	38
	4.2.2.1 Event number : 3	39
	4.2.2.2 Event number : 7	42
	4.2.2.3 Event number : 9	45
	4.2.2.4 Event number : 11	47
	4.2.2.5 Event number : 12	50
	4.2.3 Company C	53
	4.2.3.1 Event number : 1	54
	4.2.3.2 Event number : 4	57
	4.2.4 Company D	60
	4.2.4.1 Event number : 1	61

4.2.4.2	Event number : 2	64
4.2.4.3	Event number : 137	66
4.2.4.4	Event number : 138	69
4.2.4.5	Event number : 139	71
4.3	Classification table for source and cause of voltage sag	74
4.4	Voltage Sag mitigation technique	80
4.4.1	Uninterruptable power supply (UPS)	80
4.4.2	Voltage stabilizers	82
5	CONCLUSION	84
5.1	Conclusion	84
5.2	Future work	85
	REFERENCES	87

LIST OF TABLES

TABLE NO.	TITLE	PAGE
1.1	Short duration variations for voltage sags	3
2.1	Test level and duration for voltage sags	13
2.2	Losses at KTHP in 2007 & 2008 due to voltage sag	18
2.3	Losses at Silterra Malaysia from 2007 until 2010	19
3.1	Detection method based on RMS voltage	31
4.1	Voltage sags events in various industry	29
4.2	Data for event number 25	31
4.3	Test level for voltage sags event number 25	32
4.4	Data for event number 28	33
4.5	Test level for voltage sags event number 28	34
4.6	Data for event number 31	35
4.7	Test level for voltage sags event number 31	37
4.8	Data for event number 3	39
4.9	Test level for voltage sags event number 3	41
4.10	Data for event number 7	42
4.11	Test level for voltage sags event number 7	44
4.12	Data for event number 9	45
4.13	Test level for voltage sags event number	46
4.14	Data for event number 11	47
4.15	Test level for voltage sags event number 11	49
4.16	Data for event number 12	50
4.17	Test level for voltage sags event number 12	52
4.18	Data for event number 1	54
4.19	Test level for voltage sags event number 1	56
4.20	Data for event number 4	57
4.21	Test level for voltage sags event number 4	59
4.22	Data for event number 1	61
4.23	Test level for voltage sags event number 1	63
4.24	Data for event number 2	64

4.25	Test level for voltage sags event number 2	66
4.26	Data for event number 137	66
4.27	Test level for voltage sags event number 137	68
4.28	Data for event number 138	69
4.29	Test level for voltage sags event number 138	71
4.30	Data for event number 139	71
4.31	Test level for voltage sags event number 139	73
4.32	Classification table for source and cause of voltage sag	74

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Definition of voltage sag disturbances (IEEE 1159:1995)	2
1.2	A voltage sag - Voltage sag in one phase in a time domain	2
2.1	ITIC curve	8
2.2	ITIC curve (revised curve-2000)	9
2.3	CBEMA curve	10
2.4	SEMI F47	11
2.5	IEC 61000-4-34	12
2.6	Commonly occurred power quality problem	17
3.1	Series of methodology flow	21
3.2.	Power Analyzer software	23
3.3	Example of the curve.	24
3.4	Custom Voltage Tolerance Curve Selection	24
3.5	Flowchart of the detection method based on RMS voltage	27
4.1	Percentage of voltage sags event at Company A	30
4.2	Event number 25 - Triggered Phase B	31
4.3	Event number 25 according to IEC 61000-4-34	32
4.4	Event number 28 - Triggered Phase B	33
4.5	Event number 28 according to IEC 61000-4-34	34
4.6 (a)	Event number 31 - Triggered Phase A	36
4.6 (b)	Event number 31 - Triggered Phase B	36
4.6 (c)	Event number 31 - Triggered Phase C	36
4.7	Event number 31 according to IEC 61000-4-34	37
4.8	Percentage of voltage sags event at Company B	38

4.9 (a)	Event number 3 - Triggered Phase A	39
4.9 (b)	Event number 3 - Triggered Phase B	40
4.9 (c)	Event number 3 - Triggered Phase C	40
4.10	Event number 3 according to IEC 61000-4-34	41
4.11 (a)	Event number 7 - Triggered Phase A	43
4.11 (b)	Event number 7 - Triggered Phase B	43
4.11 (c)	Event number 7 - Triggered Phase C	43
4.12	Event number 7 according to IEC 61000-4-34	44
4.13	Event number 9 - Triggered Phase B	45
4.14	Event number 9 according to IEC 61000-4-34	46
4.15 (a)	Event number 11 - Triggered Phase A	47
4.15 (b)	Event number 11 - Triggered Phase B	48
4.15 (c)	Event number 11 - Triggered Phase C	48
4.16	Event number 11 according to IEC 61000-4-34	49
4.17 (a)	Event number 12 - Triggered Phase A	50
4.17 (b)	Event number 12 - Triggered Phase B	51
4.18	Event number 12 according to IEC 61000-4-34	51
4.19	Percentage of voltage sags event at Company C	53
4.20 (a)	Event number 1 - Triggered Phase A	54
4.20 (b)	Event number 1 - Triggered Phase B	55
4.20 (c)	Event number 1 - Triggered Phase C	55
4.21	Event number 1 according to IEC 61000-4-34	56
4.22 (a)	Event number 4 - Triggered Phase B	57
4.22 (b)	Event number 4 - Triggered Phase C	58
4.23	Event number 4 according to IEC 61000-4-34	58
4.24	Percentage of voltage sags event at Company D	60
4.25 (a)	Event number 1 - Triggered Phase A	61
4.25 (b)	Event number 1 - Triggered Phase B	62
4.25 (c)	Event number 1 - Triggered Phase C	62

4.26	Event number 1 according to IEC 61000-4-34	63
4.27 (a)	Event number 2 - Triggered Phase B	64
4.27 (b)	Event number 2 - Triggered Phase C	65
4.28	Event number 2 according to IEC 61000-4-34	65
4.29 (a)	Event number 137 - Triggered Phase B	67
4.29 (b)	Event number 137 - Triggered Phase C	67
4.30	Event number 137 according to IEC 61000-4-34	68
4.31 (a)	Event number 138 - Triggered Phase A	69
4.31 (b)	Event number 138 - Triggered Phase C	70
4.32	Event number 138 according to IEC 61000-4-34	70
4.33 (a)	Event number 139- Triggered Phase B	72
4.33 (b)	Event number 139 - Triggered Phase C	72
4.34	Event number 139 according to IEC 61000-4-34	73
4.35	Percentage of the source of event	79
4.36	Percentage of the cause of event	79
4.37	Block diagram for UPS	80
4.38	Voltage stabilizers	82

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this modern year, a sophisticated and technologically based electronics were widely used among the customer's facility. Recently, the power quality problems have become a greatest concern among the utilities, manufacturers and the consumers as it will cause a huge loss in the production in term of maintaining, cost and time. In fact, the common denominator of any kind of power quality problems is cost. Power quality is also be known as a dirty power, which define as a power which has a distorted sinusoidal in the currents or voltages, or operates beyond their designated current or voltage limits / tolerance.

There are various kinds of power quality problems such as voltage sags (dips), harmonics, voltage swell, under voltages, voltage unbalance, electrical noises interruption and also voltage fluctuations. Among all these types of power quality problems, there are two major concerns for both utilities and the consumers, which are voltage sags and harmonics. This research will be focusing more on the voltage sags.

Figure 1.1 below shows a various type of power quality problem.

E v e n t	110%	Transients	Swell		High voltage
	90%	Normal operating voltage			
M a g n i t u d e	10%	T r a n s i e n t	Voltage Sag		Under voltage
			0.5 cycle	3sec	1 min
		Momentary		Temporary	Sustained interruption
		Event duration			

Figure 1.1: Definition of voltage disturbances (IEEE 1159:1995) [1]

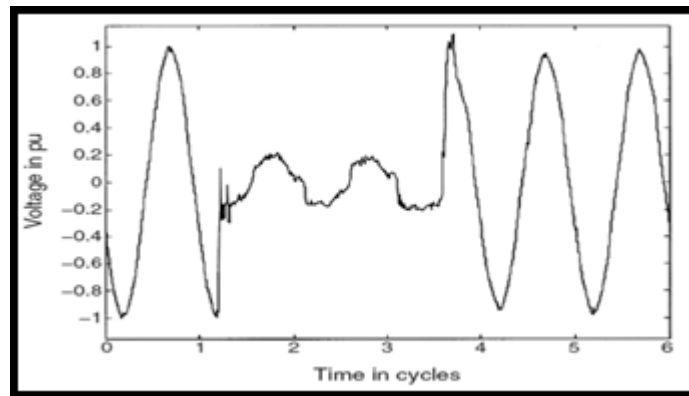


Figure 1.2: A Voltage Sag – Voltage sag in one phase in a time domain

The definition of voltage sag is variously described by International Electrotechnical Commission (IEC) and Institute of Electrical and Electronic Engineering (IEEE) standards. IEC standard [2] describes voltage sag (dips) as a sudden reduction of the voltage at a point in the electrical system, followed by a voltage recovery after a short period of time, from 0.5 cycles to a few seconds, meanwhile IEEE standard [3] describes voltage sag as a decrease to between 0.1 to 0.9 Pu in rms voltage (or current) at the power frequency, for the duration of 0.5 cycles to 1 minute. As shown in Figure 1.1, there are few types of voltage sags which are instantaneous, momentary and temporary. Table 1.1 below will categorize these voltage sags as to their category.

Table 1.1: Short duration varies (Voltage sags)

Short duration varies (Voltage sags)			
No.	Category	Duration of sag	Voltage magnitude in per unit
1	Instantaneous	0.5 – 30 cycles	0.1 – 0.9 pu
2	Momentary	30 cycles – 3s	0.1 – 0.9 Pu
3	Temporary	3s – 1 minute	0.1 – 0.9 pu

The common causes of voltage sags are identified to be; [1] the starting of large motor loads, faults on other branches of the supply network and faults in the internal supply scheme of the customer's installation. Although the utility side has done their best to provide a clean voltage to the customers, but the external factors that can cause a fault to occur, such as lightning, crane encroachment, tree encroachment and birds are beyond their control. Some of the electronic equipment, especially, are very sensitive towards the voltage sags. These equipment will trip or malfunction whenever the rms voltage drops to below 90% of their nominal voltage for the duration of longer than 1 or 2 cycles.

This is why the voltage tolerance curve, which set the immunity area for a safely operate equipment were needed in the case involving a sensitive equipment. There are few voltage tolerance curves which are widely used by the utilities, manufacturers and customers as their references. These voltage tolerance curves include Information Technology Industry Council (ITIC) curve; which formerly known as Computer and Business Equipment Manufacturers' Association (CBEMA) curve, Semiconductor Equipment and Materials International (SEMI) F47 and MS IEC 61000-4-34 (input current less than 16 A) / MS IEC 61000-4-11 (input current more than 16 A).

1.2 Project background

The seldom occurrence, yet having a greater effect of voltage sags in Malaysia is a major concern to the company and the utility companies. This project is to analyze the voltage sags event mainly in term of the depth sags, the source of the voltage sags and the cause of voltage sags. Since there are mitigation techniques that can be applied to the equipment for both customer and utility side, few suggestions of the mitigation technique will be discussed in this report. The analysis of the events is being done by the Power Analyzer software.

1.3 Problem statement

Voltage sags is one of a kind of problem in power quality. It can cause large losses in a production cost even though it is a reduction in voltage for a very short time. The utility may have tried their best in supplying the best power to the consumer, but the fact that voltage sags might occur with a certain cause cannot be avoided. To conduct a good research on voltage sags, one has to know about voltage sags, such as:

- What are voltage sags?
- What are the cause and effect of voltage sags?
- Usually when the voltage sags occur?
- What is the source of disturbance in industrial sector?
- Whose fault it is when this kind of event (voltage sag) occurs?
- Where does the voltage usually occur?
- What is the characteristic of voltage sag?

Who contribute to the voltage sag events? There are widespread beliefs among the utility customers that the voltage sag is problem that only originated from the utility system [1]. It is actually caused either by the customers or the utilities. So, between the customer and the utilities, which side contribute more on the voltage sag occurrence in Malaysia?

1.4 Objectives

There are few objectives of this research:

1. To study and identify the main causes of the voltage sag events.
2. To determine the source of disturbances in industrial sector.
3. To analyze voltage dips event using Power Analyzer Software.
4. To suggest a suitable mitigation technique for each type of cause of voltage sag involved.

1.5 Scope of Work / Limitation

1. Study and analyzing the voltage sags event in low and medium industry.
2. Reviewing the standards of voltage sag and ensure that the equipment involve comply with the standards (ITIC curve (formerly known as CBEMA curve), SEMI F47, IEC 61000 4-34 / IEC 61000 4-11, ANSI curve and so on)

REFERENCES

- [1] TNB Power Quality Guide Books
- [2] IEC 1000-2-1 – 1990 – Part 2: Environment – Section 1: “Description of the environment – Electromagnetic environment for low-frequency conducted disturbances and signaling in public low-voltage power supply system”
- [3] IEEE p1346 “ Recommended Practice for Evaluating Electric Power Systems Compatibility with Electronic Equipment – Working Group Electric Power System Compatibility with industrial process equipment –pt1- Voltage Sag’s” Industrial & Commercial Power System of May 1994 (Draft)
- [4] Standards and Guideline Referring to Power Quality.
- [5] Mario Fabiano Alves, Tatiana Nesralla Ribeiro, ‘Voltage Sag: An Overview of IEC and IEEE Standards and Application Criteria’
- [6] Voltage Sag Immunity Standards – Semi F47 and F42-
- [7] Surya Hardi, Ismail Daut, ‘Sensitivity of Low Voltage Consumer Equipment to Voltage Sags’.
- [8] Bakri Sawir (TNB), Mohd Ruddin Ab. Ghani, Abdullah Asuhaimi Mohd Zin, Abdul Halim Mohd Yatim(UTM Skudai), Hashim Shaibon Shaibon(Akademi Tentera KL), Kwok Lun Lo(University of Strathclyde Glasgow, UK), ‘Voltage Sag : Malaysian’s Experience’.

- [9] John Horak, 'Power Quality: Measurements of Sags and Interruptions'.
- [10] Dong-Jun Won, Seon-Ju Ahn, Il-Yop Chung, Joong-Moon Kim, Seung-II Moon, 'A New Definition of Voltage Sag Duration Considering the Voltage Tolerance Curve'.
- [11] Jeff Lamoree, Dave Mueller, Paul Vinett, William Jones, 'Voltage Sag Analysis Case Studies'.
- [12] G. Alonso Orcajo, J. M. Cano R., C.H. Rojas G., M.G. Melero, M.F. Cabanas, F.Pedrayes, 'Voltage Sags in Industrial System'.
- [13] Ding Ning, Cai Wei, Suo Juan, Wang Jianwei, Xu Yonghai, "Voltage Sag Disturbance Detection Based on RMS Voltage Method", 2009, IEEE.
- [14] Mark St Stephens, "Power Quality Standards : CBEMA, ITIC, SEMI F47, IEC 61000-4-11/34", Electric Power Research Institute.
- [Available online : industrial.sceg.com]
- [15] M. Manjula, A.V.R.S. Sarma, Sukumar Mishra, " Detection and Classification of Voltage Sag Causes based on Empirical Mode Decomposition", IEEE.
- [16] Alexis Poycarpou, " Voltage Sag Indices in Electrical System : Standard and Development",2009.