THE EFFECTIVENESS OF VOLTAGE SAG MITIGATION ON CHILLER UTILITIES EQUIPMENT TO COMPLY SEMI-F47

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by

ARIVINDHARAO A/L APPANA

(1432221150)

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UNIVERSITI MALAYSIA PERLIS

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LIST OF ABBREVIATIONS

ELCB	Earth leakage circuit breaker
AC	Voltage alternative current
ITIC	Information Technology Industry Council
CBMEA	Computer Business Equipment Manufacturers Association
SEMI F47	Semiconductor Equipment Materials International.
A	Ampere
IEEE	Institute of Electrical and Electronics Engineers
VFD	Variable Frequency Drive
RMS	Root-Mean-Square
MCCB	Moulded Case Circuit Breaker
V	Voltage
%	Percentage
UCL	Upper Control Limit
LCL	Lower Control Limit

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KEBERKESANAN PENGGUNAAN ALAT KAWALAN PENURUNAN VOLTAN TERHADAP PERALATAN PENDINGIN UNTUK MEMATUHI PIAWAIAN SEMI-F47

ABSTRAK

Tujuan tesis ini adalah untuk mengkaji keberkesanan penggunaan alat kawalan penurunan voltan terhadap pada peralatan pendingin litar kawalan untuk mematuhi piawaian SEMI-F47.Tesis ini menggunakan pengukuran yang menyeluruh data dan analisis mengenai trend voltan pada tempoh yang dipilih dilitar kawalan pendingin.Piawain SEMI-F47 membenarkan voltan menurun mendadak 50% dalam 0.3saat daripada voltan norminal.Semua yang berkaitan dengan pengukuran data telah diambil di sebuah syarikat semikonduktor kawasan peridustrian Bayan Lepas Pulau Pinang.Untuk mencapai matlamat ini adalah penting untuk memilih peranti penurunan voltan yang bergantung kepada persekitaraan kerja dan peralatan fizikal.Allan Bradly Buletin 1680P ProDySc 25 mampu untuk mengurangkan penurunan voltan, yang menyumbang kea rah penambahbaikan terhadap kestabilan voltan jika tertakluk kepada penurunan voltan. Terdapat had voltan dan julat semasa diberi pilihan terhad pemilihan peralatan. Kajian ini memberi pengetahuan yang memdalam mengenai kepentingan dan faedah pengurangan penurunan voltan kepada kualiti voltan yang signifikan dengan meningkatkan kecekapan peralatan untuk memenuhi SEMI-F47 dalam operasi. Tesis ini adalah sangat asli untuk mengukur keberkesanan alat kawalan penurunan voltan yang dipasang pada peralatan pendingin yang mempunyai ketetapan voltan dan pola masa.

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THE EFFECTIVENESS OF VOLTAGE SAG MITIGATION ON CHILLER UTILITIES EQUIPMENT TO COMPLY SEMI-47

ABSTRACT

The purpose of this thesis is to study the effectiveness of voltage sag mitigation on chiller controller equipment to comply SEMI F47 standards. The thesis adopts a comprehensive data measurement and analysis on voltage trend on selected duration on chiller control circuit. SEMI F47 standards specification allow the voltage sag 50% within 0.3sec from the nominal voltage are acceptable range. All related data measurement were taken at a semiconductor company in Bayan Lepas Industrial Park, Penang. To achieve this, it is essential to properly select voltage sag device depending on working environment and physical equipment. Allen Bradly Bulletin 1608P ProDySC25 is capable for voltage sag mitigation, which contributes towards improvements on voltage stability if subjected to voltage sags. There are limitations of the voltage and current ranges given the restricted choice of equipment selection. This study provides in-depth knowledge on the importance and benefits of voltage sag mitigation, in its contribution to significant voltage quality with increasing total equipment efficiency to meet SEMI-F47 in business operations. This thesis is very original as on highly accurate voltage and duration trends measured on actual performance of voltage sag device hooked-up on chiller controller equipment as real-time.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The manufacturing industry among developing nations is growing tremendously. It varies depending on scale of size from light industrial companies to semiconductor, multinational and heavy-industrial types. There is rising awareness on unavoidable electrical utility expenses to support industry's operations that is on increasing trend due to tariff revisions contributed from scarce resources to generate clean and quality energy. Many also will attempt to avoid maximum electrical kilowatt-hour peak while operating due to higher tariff demand charges.

Globally, companies are paying extra attention to search and source for viable alternative quality energy sources as well as strategies to avoid voltage sag incidents. Focusing on Malaysia, this country has several voltage sag incidents equivalent to poor power quality interruptions happening almost on monthly basis, and more frequent especially during monsoon season.

Such concern has garnered much attention from facilities department, factory owners, and building managers, ever since the manufacturing industry started to establish in Malaysia late 1970s by foreign investors. Many types of voltage sag protection devices were developed along the way, which are also referred as power filters, uninterrupted power supply (UPS), voltage corrector and variable frequency drive (VFD) relay to hold last state. They have, to certain extent, successfully minimize power quality interruptions during company's round the clock operating hours.

Majority of the public are often confuse on the right terminology to describe power quality interruptions, which in fact easily refer as voltage sag or voltage dip. Due

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to shift of maximum peak demand and overall usage of the electrical utility in the manufacturing industry, many are starting to install monitors to capture incoming voltage quality trend (including remaining and retaining sag), early detection system to alert operators on voltage sags and metering to capture overall kilowatt demand usage.

With multiple and complex features to be included in a single system, companies have to be ready to invest to construct a centralized voltage system with redundancy within their site. With trained personnel and restricted control access, super users will able to easily, quickly and proactively address potential voltage sag issues, by using voltage sag protection devices installed such as variable frequency drive (VFD), uninterrupted power supply (UPS), contactors, relays and Integrated Electronics Engineering Centre (IEEC) approved electrical equipment. Information technology equipment like data centre servers and induction motors are highly sensitive to voltage sag interruptions, thus with voltage sag protection devices, the chances for impact will be much reduced.

1.2 Problem Statement

To avoid voltage sag, uninterrupted and reliable voltage are required for the dedicated loads, where in ideal situation, a constant voltage must be fed continuously into the electrical distribution boards. Stability of voltage has been and continuously become a major concern. Start from upstream, if external Tenaga Nasional Berhad (TNB) transmission lines at any time losses its synchronism within the system will lead to significant voltage fluctuations. Depending on the quantity of the disturbance either in small or large (in percentage of remaining voltage), will have different consequential effects. Normally severe voltage sags, refers to single or 3-phase equipment with remaining 70% or loss of 30% voltage, which are likely to cause equipment operations to be interrupted.

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For example, on a 3-phase incoming voltage of 415V impacted by severe voltage sag, it will have remaining voltage of 290.5V and for the case of single-phase of similar incoming voltage, 168V is the remaining voltage.

The capability of the electrical distribution system to sustain synchronism due to small disturbances or minor variations in loads is classified as dynamic stability. From stability perspective at end user, voltage stability corrector devices are recommended, because of extra advantages over voltage sag protection devices as they are maintenance-free with unparalleled energy efficiency. Further elaboration is covered under Chapter 2: Literature Review following recommendations proposed by researchers of latest and more efficient design of a voltage sag corrector that reportedly able to outperform basic conventional correctors.

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1.3 Aims and Objectives

The aim of the research is to improve the electrical system to counter or avoid voltage sag interruptions. Sample model used in this research is Allen Bradley pro DySc Dynamic Sag corrector. This voltage stabilizer is able to maintain and quickly recover system dynamic stability on the load after being subjected to small disturbances in the incoming voltage.

The specific objectives of this research can be summarized as follows:

1. To reduce above 50% from the nominal incoming voltage sag interruptions within 0.3sec for High pressure chiller equipment load following SEMI F47.
2. To minimize chiller start up time without entering into fully unload condition or with mid-way with remaining load during a voltage sag event.

3. To simulate and observe effects of voltage sag changes – from 90% to 50% voltage sag in the system after being equipped with voltage sag corrector (pre- and post-monitoring with data collection).

1.4 Scope of Project

This research investigates the performance ability "in terms of reduction of voltage sag interruptions and time of recovery" of the Pro DySC dynamic sag voltage corrector before and after installation. Simulation testing on the voltage corrector is conducted by using isolator circuit to create various scenarios, firstly in bypass mode followed by normal and test mode. The corrector is advised to be installed at the plant room, with certain distance to running equipment and within ambient temperature (below 40°C) environment to avoid damage to corrector's internal components. A single model and type is used consistently throughout the research that is Allen Bradley's brand pro DySc 25 Amp voltage sag corrector.

The project kicks-off by installing voltage sag corrector electrical cabling inside equipment control circuit board at control circuit contactor device, followed by simulation testing before and after installation of voltage sag corrector. During actual simulation, should proceed with monitoring and obtaining results as captured by the voltage sag corrector.

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1.5 Outline of the Thesis

The dissertation of this research is divided into five chapters.

Chapter 1 introduces project overview, objectives, scope of research and the problem statement.

Chapter 2 consists review of current methods on reducing voltage sag events. The review focuses on techniques can be used to counter or avoid voltage sag

Chapter 3 explains in detail and describes the methodologies used in this research. This chapter presents the simulation testing the control panel which are connected with the voltage sag corrector.

Chapter 4 is on the analysis of simulation results and models presented in Chapter 3 of the voltage after being subjected to small disturbances.

Chapter 5 states the conclusion of the research. The conclusion of this study is based on the result and discussion that obtain from previous Chapter 4. Recommendations for future researches will also be included in this chapter.

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CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Currently voltage quality have been under much more stressful conditions compared to the previous years, with increased electricity consumption in heavy loaded areas and so on where it is not feasible or economical. Under these stressful conditions, it may imposed unstable voltage system such as sudden voltage drops where sometimes it can escalate to the form of voltage collapse or voltage instability. The presence of these oscillations is traced to fast voltage regulation in semi-conductor industries and to be overcome using additional control by adding voltage stabilizer. A number of such incidences have been experienced globally. Therefore, voltage stability now has become a grievous concern in private sector manufacturing, thus tremendous amount of research works were carried out by the researchers around the globe in attempt to overcome the situation.

A sag is a decrease in Root Mean Square (RMS) voltage to between 0.1 pu and 0.9 pu for durations from 0.5 cycles to 1 min. Typical values are between 0.1 pu and 0.9 pu. Terminology used to describe the magnitude of a voltage sag is often confusing. A "20% sag" can refer to a sag that results in a voltage of 0.8 pu or 0.2 pu. The preferred terminology when describing RMS variations is retained voltage or remaining voltage. Therefore, in the absence of standard guideline, remaining voltage is assumed throughout this recommended practice. Just as an unspecified voltage designation is accepted to mean phase-to-phase voltage, so an unspecified sag magnitude will refer to the remaining voltage.

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For example, an 80% sag refers to a disturbance that resulted in a voltage of 0.8 pu. Where possible, also specify the nominal, or base, voltage level. Expanding on the previous example, an 80% sag will result in different voltage levels if the nominal is 460V (remaining voltage of 368V) or 480V (remaining voltage of 384V).

2.2 Safety

There are numerous concerns with regards to safety, including personnel safety, equipment safety, and system safety. For safety reasons, power monitoring equipment should pass the safety standards that are appropriate for the jurisdiction where the equipment will be used. Additionally, good grounding practices should be observed so that the touch potential of the enclosure should be within safe limits and ground loops are not created. The placement/mounting of the instrument, either directly or within the properly rated NEMA-type enclosure for the environment, should not interfere with normal facility operations.

Especially safety-related measures such as light curtains. Connection of the measuring inputs is covered in Clause 7. However, improper connection of communication equipment (e.g., telephony, internet, and instrumentation-PLC I/O, RS232/485, radio and power line carrier) can affect not only those media, but the measurements themselves.

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2.3 Regulation

In Malaysia, any electrical regulation must refer with local energy commission department called Suruhanjaya Tenaga. They decide the Regulation and Act for electrical supply based on that Malaysia's incoming voltage to end user, so to be -6% and +10% meaning any range of incoming supply must be within this range, which are supplied by Tenaga Nasional (TENAGA, 2012 Edition)

Nominal voltage effective 1st Jan 2008, for low voltage supply in Malaysia is 230/400V (+10%, -6%) in accordance with MS IEC 60038. The details of voltages and variations are as below:-

Nominal Voltage (V) Percentage of Variations (± %) Voltage Variations (V) Min. Max.

Table 2.1: Low Voltage and Variations

Description	Nominal Voltage (V)	Percentage of Variations (%)		Voltage Variations (V)	
		-	+	Min	Max
Until 31/12/2007					
Single phase 1 Ø	240	10	5	226	252
Three phase 3 Ø	415	10	5	373.5	436
Commencing on 1/1/2008					
Single phase 1 Ø	230	6	10	216	253
Three phase 3 Ø	400	6	10	376	440

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2.4 Steady-State Supply Voltage Performance

(Nasional, Second (2nd) Edition in 2007) Steady-state voltage fluctuation under normal condition, when all circuit elements are in service, the distribution network including the points before the consumer metering must be planned to be maintained as fluctuation limits under normal conditions.

Table 2.2: Steady State High Voltage Level

Voltage Level	% Variation
400v and 230v	-6% & +10%
6.6kv,11kv,22kv,33kv	+/- 5%
132kv and 275kv	-5% & +10%
500kv	+/- 5%

Steady-State Voltage Fluctuation under Contingency Condition.

During critical condition, end users that face power outage on one or more circuits, the voltage level at all points in the distributor's distribution at consumer metering is obliged to retain readings as per in the tables:

Table 2.3: Steady State Voltage Fluctuation

Voltage Level	% Variation
400V and 230V	+/-10%
6.6kV,11kV,22kV,33kV	+/-10%
132kV and 275kV	+/-10%
500kV	-10% & +5%

2.5 IEEE Regulation

For past few years, IEEE had recommended monitoring the voltage quality to study the occurrences of voltage dip. The voltage dip is defined as decrease of RMS voltage from 90% to 10 % of voltage normal value with duration length between half a cycle and 1 min. There are disturbances caused by many reasons that usually linked to system faults. There are situations whereby voltage dip caused by heavy load switching, relay calibration or starting up heavy load equipment during peak hours. Voltage dip events have become very important and noticeable from their influence on majority of connected load to main power system. Most equipment will trip if falls below 90 % voltage dip for more than one or two cycles.

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According to IEEE regulation (1159™-2009, 18 March 2009) on voltage dips, instantaneous interruption can contribute to equipment to suddenly cease operation or shutdown without prior planning. Electronic equipment covers all of power and electronic controllers, computers and electronic controls for rotational equipment. Low-medium voltage sag practically cause tools to stop operating and may cause drop-out of induction motor contactors. There are sample cases of medium-high voltage sag that may cause impairment to electronic tools particularly during such abrupt dip and recovery of the voltage.

2.6 Voltage Sag

Short-time voltage dips potentially create minor process disturbances. Frequently the sag is detected by electronic process controllers armed with fault-detection circuit board that initiates shutdown of other less-sensitive loads. Additionally, control power systems and emergency stop circuits that use hard-wired relay logic and contactors can be highly sensitive to sag. A common solution is to serve the electronic controller with a constant-voltage transformer, or other mitigating device, to provide adequate voltage to the controller or contactor/ relays during a sag.

The application challenges the electronic controller to sustain through sags so not to damage process equipment protected by the fault circuitry or compromise safety systems, while simultaneously reduce nuisance shutdowns. Electronic devices with battery backup should be unaffected by short-duration reduction in voltage. Only when power supply for electronic-based equipment are wrongly operated (eg. ON and OFF equipment electronic switches too frequently and etc.), prior to tripping can caused unintended energy storage loss from DC bus capacitors. Tools such as switchgear, cable, transformers, bus, current transformer and potential transformer should not experience

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damage or breakdown during short-time sags. Just a small speed variation of induction machinery and a slight reduction in output from a capacitor bank can happen during a sag.

For example, consider a system with a contactor connected between the power source and an induction motor. If occur voltage sags, the motor will experience not only the sag, but perhaps a momentary or sustained interruption if the contactor bounces or opens during the sag.

2.7 Swells

An upsurge in voltage wave to tools beyond nominal range can cause damage to mechanisms whereby subjected to swell level, and electronic controller's instantaneous failure modes during such situations. Many modern electronic devices incorporate integral over-voltage tripping in their designs. The actual electronics are often not disconnected from the source if the device trips and can still incur damage. Cables busses, current transformers, potential transformers, switchgear and rotating machinery may have a shorter equipment lifespan.

A momentary upsurge in voltage on some protecting relays may affect in unwanted actions while others will not be impacted. Repeated voltage swells on a capacitor bank can affect the single capacitor to bulge while output is increased from the bank. The building's light output from electronic control or electronic stabilizer devices may be increased during a temporary swell. Securing type surge protective devices, thyristor, and silicon avalanche diodes may be destroyed by swells exceeding their maximum continuous operating voltage rating.

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Table 2.4: Categories and Typical Characteristics of Power System Electromagnetic Phenomena

Categories	Typical spectral content	Typical duration	Typical voltage magnitude
Short –Duration root –			0.1-.0.9 pu
mean-square (RMS)			1.1-1.8 pu
Instantaneous		0.5 -30 cycles	
Sag		0.5 -30 cycles	<0.1 pu
Swell			0.1-0.9 pu
Momentary		0.5 cycles -3s	1.1-1.4 pu
Interruption		30 cycles-3s	
Sag		30 cycles-3s	<0.1 pu
Swell			0.1-0.9 pu
Temporary		>3s-1min	1.1-1.2 pu
Interruption		>3s-1min	
Sag		>3s-1min	
Swell			

These terms and categories are applied to voltage quality measurements. They are distinguised differently from terms defined in IEEE Std 1366-2003, as well as in other reliability-related standards, recommended practices or guides.

2.8 Semi-F47 -0706

Reaching millennium century, semiconductor manufacturers, compliance testing companies and tools suppliers have amassed a significant technical and practical knowledge base that correlated to testing. This has increased the drive to develop good standards. The original SEMI F47-0200 (voltage sag immunity) is considered highly successful in cutting down service costs while increasing tool reliability and uptime. New SEMI F47-0706 compliance is defined by passing three test points rather than compliance to a curve as defined in SEMI F47-0200. The voltage sag immunity at different Hz levels are tabulated below.

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