Improvisation on Voltage Sag Occurrences at UniMAP Pauh through Implementation of D-STATCOM

by

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LIST OF ABBREVIATION

AC	Alternate Current
CB	Circuit Breaker
D-STATCOM	Distribution Static Compensator
DC	Direct Current
DVR	Dynamic Voltage Restoration
GTO	Gate Turn Off Thyristor
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated Gate Bipolar Transistor
PSCAD	Power System Computer Aided Design
SVC	Static Var Compensator
VI	Inverter Voltage
VS	System Voltage
VSC	Voltage Source Converter
VSI	Voltage Source Inverter
VSR	Voltage Source Rectifier

Pengurangan Pada kenduran Voltan Yang Terjadi Di Menara Penyejukan Melalui Pelaksanaan D-STATCOM

ABSTRAK

Di dalam sistem kuasa, salah satu masalah kualiti kuasa yang terjadi adalah kenduran voltan di mana kebanyakannya berlaku di dalam sektor industri. Kenduran voltan adalah pengurangan voltan rms pada tempoh yang tertentu atau kitaran tertentu dalam tempoh masa yang singkat. Kenduran voltan merujuk kepada berkurangannya voltan rms di antara 0.1 pu ke 0.9 pu dalam tempoh masa 0.5 kitaran hingga ke 1 minit. Kenduran voltan biasanya disebabkan oleh kesalahan dalam sistem namun ia juga disebabkan oleh permulaan motor besar atau penukaran ke beban yang lebih berat. Salah satu penyelesaian yang boleh digunakan untuk mengurangkan atau menambah baik kenduran voltan adalah dengan menggunakan Pengagihan Pemampas Statik (D-STATCOM). Ia adalah pengawal kuasa yang memberikan voltan fleksibel yang dikawal dengan ciri-ciri tindak balas yang cepat untuk menyediakan peningkatan kepada kualiti sistem kuasa. Apabila voltan penyonsang adalah kurang daripada voltan sistem, D-STATCOM akan menyuntik kuasa reaktif kepada sistem dan apabila voltan sistem lebih tinggi daripada voltan penyonsang, D-STATCOM akan menyerap kuasa reaktif tersebut. Litar projek ini di bina di dalam perisian Reka Bentuk Sistem Kuasa Berbantukan Komputer (PSCAD) dan semua parameter akan di reka bentuk berasaskan pada ciri-ciri rangkaian sistem kuasa. Terdapat dua jenis Penukaran Kuasa Voltan (VSC) yang merupakan Penyonsang Kuasa Voltan (VSI) dan Penerus Kuasa Voltan (VSR). VSC menggunakan suis semikonduktor sebagai suis dan menggunakan denyutan untuk menghidupkan suis tersebut. Dengan merujuk kepada kelebihan dan kekurangan, pintu mematikan thyristor (GTO) akan digunakan sebagai suis untuk VSC tersebut. DC kapasitor memainkan peranan yang penting dalam menyimpan tenaga yang digunakan untuk mengurangkan kenduran voltan. Ia digunakan untuk membekalkan kuasa reaktif melalui D-STATCOM apabila kenduran voltan berlaku. Dalam simulasi ini, motor aruhan tiga fasa telah digunakan sebagai beban. Data motor diambil dari motor sebenar dalam menara penyejukan berhampiran PPKSE di UniMAP. Tanpa menggunakan D-STATCOM, tempoh kenduran voltan adalah kira-kira 0.5s untuk kedua-dua kejadian mengendur dan kenduran voltan akan hilang secara perlahan-lahan apabila motor induksi mencapainya kelajuan yang sebenar. Kenduran voltan yang berlaku dalam sistem simulasi mempunyai pengurangan voltan sebanyak 40% (tertinggi) dan 28% (terendah). Merujuk kepada piawaian IEEE, ia membuktikan bahawa pengurangan kejadian voltan adalah di antara 10% - 90% dalam tempoh 0.5 kitaran 1 minit. Dengan menggunakan D-STATCOM, ia menunjukkan bahawa kenduran voltan yang telah berjaya dikurangkan sebanyak 99%. D-STATCOM memberikan sumbangan besar dalam mengoptimumkan isu kualiti kuasa dalam pengedaran rangkaian yang tidak stabil.

Mitigation on Voltage Sag Occurrences at Cooling Tower through Implementation of D-STATCOM

ABSTRACT

In power system, one of the power quality problems is the voltage sag that mostly occurs in the engineering. The voltage sag is the reduction of the rms voltage at the certain period or certain cycle in a short period of time. Voltage sag refer to decreasing of rms voltage in between 0.1 pu to 0.9 pu in a period of 0.5 cycle to 1 minute. Voltage sag commonly caused by fault within the system however it is also caused by the starting of large motor or switching of a heavy load. One of the solution that can be applied to mitigate or improvise the voltage sags is by using the Distribution Static Compensator (D-STATCOM). It is a power controller that gives a flexible voltage controlled with a fast response characteristic to provide a power system quality improvement. When the system voltage is lower than inverter voltage, D-STATCOM will inject reactive power to the system and when the system voltage is higher than inverter voltage, the D-STATCOM will absorb the reactive voltage. The circuit is design in the Power System Computer Aided Design (PSCAD) software and all parameter will design base on the power system network characteristic. There are two type of Voltage Source Converter (VSC) that is voltage source inverter (VSI) and voltage source rectifier (VSR). These VSC used semiconductor switches as the switching devices and the pulses will trigger those switches. By referring to advantage and disadvantages, gate turn off thyristor (GTO) will be used as the switching device. DC capacitor play an important role in storing the energy that used to mitigate voltage sags. It is used to supply the reactive power through D-STATCOM when voltage sags occurs. In this simulation, the three-phase induction motor has been used as the load for the AC system. The data of the motor was taken from the real motor in cooling tower near the PPKSE School at UniMAP. Without using the D-STATCOM, the sag duration was about 0.5s for both sag occurrences and the voltage sag were slowly disappear when the induction motor reach it rated speed. The voltage sag that occurs in the simulation system has a reduction of voltage for 40% (the highest) and 28% (the lowest). From the IEEE standard, it prove that the decreasing of voltage occurrences is in between 10% - 90% in a period of 0.5 cycle to 1 minute. By implementing D-STATCOM, it shows that the voltage sag has been 99% completely being mitigated. D-STATCOM gives a huge contribution for optimizing power quality issue in unbalances distribution network.

CHAPTER 1

INTRODUCTION

1.1 Overview

In power system, one of the power quality problems is the voltage sag that mostly occurs in the industries. The voltage sag is the reduction of the rms voltage at the certain period or certain cycle in a short period of time (Lamoree et al., 2010). In other word, voltage sag can also be defined as the voltage that were being supplied is not meet the requirement of the load and it can severely damage the load depend on the type of load that involve. The sudden drop of voltage could reach until 90% of nominal voltage (Fuad, 2007). The voltage sag was usually caused by internal source where from the facilities itself. Such as, starting a huge load or facilities problems. It also can cause by external source where the facilities were connected with the same line network. Such as, starting huge load at other facilities, lightning strike, animals and other similar cause. Most researcher say that voltage sag occurs when there is short circuit on the power supply. It is because of current will rise when short circuit occur and large voltage drop will produce in the impedance of power supply system (Fuad, 2007).

One of the solution that can be applied to mitigate or improvise the voltage sags are by using the Distribution Static Compensator (D-STATCOM) (Varesi, 2010). D-STATCOM is a power controller that gives a flexible voltage controlled with a fast response characteristic to provide a power system quality improvement (Sajedi et al., 2011). It will be connected near the load in the system. D-STATCOM use inverter to

change the DC (Direct Current) voltage at the capacitor to a controllable voltage source by controlling the magnitude and phase (Roy & Singh, 2012). In overall, it can be stated that the D-STATCOM can be used as supplying voltage regulator to provide voltage when the sudden drop of voltage (Voltage Sags) occurs (Sajedi et al., 2011). In this project, the voltages sags that occurred in the UniMAP Pauh will be improvise by through implement of D-STATCOM by using PSCAD software.

1.2 Problem Statement

Voltage sag or also being called a momentary power interruption has been a major issues among the industries that used sensitive equipment. The drop of voltage could reach until 90 % of nominal voltage and could damage some equipment. Most industries used SVC to get the voltage stability because of the price is cheaper and it provide a good support for voltage sag occurrence, but it was not effective compared to STATCOM where it could provide a better performance compared to SVC (Bisen & Shrivastava, 2013). In this project, a system that will improvise the voltage sags will be design by implementing D-STATCOM to mitigate the sudden drop occurrences in UniMAP Pauh.

1.3 Objective of the Research

The objectives for the project are as follows:

1. To minimize the reduction of rms voltage at a certain period of time.
2. To solve the voltage sags problem by implementing D-STATCOM.
3. To improvise the voltage sag that occur by designing the circuit in the PSCAD software.

1.4 Scopes of Research

To achieve the research objective, the scope of research has been determined. The scopes of research are to reduce the sudden drop voltage to a better nominal voltage, improvise the voltage sags by implementing D-STATCOM and all worked will be conducting and simulated in the PSCAD software.

1.5 Thesis Outlines

As for Chapter 1, a review on the project was discuss on the power quality problem that is voltage sag and the solution on the power quality problem. The problem statement are discuss by referring on the effect of the power quality problem and the selection of solution device. Some objective was stated to so that the target of this project will be achieve at the end of the project. To make sure that the project running smoothly, a scope has been determined as the guide of project.

In Chapter 2, some research on the project has been done. The information that collected are regarding on the power quality problem and the solution that can be used to mitigate the power quality problem.

For Chapter 3, some explanation on method that taken on solving the power quality problem has been explain. A flow chart on project system had been constructed to show the flow of project. An explanation on circuit construction also has been provided.

The Chapter 4 is where the result has been collected and discuss. All the simulation on mitigating the power quality problem has been presented in the form of figure and all the discussion is based on the theory.

With Chapter 5 as the conclusion part, all of the discussion has been summarize and a conclusion has been made. Some recommendation on future project and limitation has been stated in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To achieve a better result output, some reviews had been done on previous related researchers. Most of the information were collected from various documentations such as journal papers, study dissertation, guidelines, and etc that related to the topic of voltage sag and D-STATCOM. Most of the reading materials delved into determination of the suitable D-STATCOM configuration in order to mitigate the voltage sag in term of voltage and reactive power adjustment.

2.2 Power Quality Problem in Power Distribution System

Power quality is defined as reliability in the concept of electronic equipment powering and grounding that is suited to its operation and compatible with the premise wiring system and other connected utilities equipment. According to Khalid and Dwivedi (2011), power quality expert's state that 50% of power quality problem were related to ground associated issues. By referring to the Almeida, Moreira and Delgado (2010). Due to the wide usage of electronic devices, the problems of power quality are becoming alarmingly worse. Thus they become distorted and create the occurrence of disturbance.

Table 2.1 shows power quality problems commonly found in power distribution system. In this paper, the power quality problem that will be discussed is voltage sags

whereas it is one of the most major problems that were encountered by most facility. Voltage sags occurrences can severely damage the sensitive equipment depend on the type of load that involve.

Table 2.1: Power quality problems and description (Almeida et al., 2010).

Power Quality Problems	Description
Voltage sag	Decreasing voltage in between 10% to 90% of the nominal voltage rms for 0.5 cycle to one minute. Usually cause by fault on transmission line, heavy load connection and large motor start up.
Short Interruption	It is the interruption of electric supply for a few millisecond to two seconds. Commonly cause by automatic enclosure of protection device, insulation failure and insulator flashover.
Long Interruption	Interruption of electric supply for a period of one to two seconds. It was cause by object that strike the lines or poles, human fault and protection device failure.
Voltage spike	Variation of voltage for a period of microseconds to milliseconds and can reach kilovolts. It was due to lightning, switching and heavy load disconnection process.
Voltage Swell	Increase in voltage for a short period of time at the power frequency. It commonly cause by start-up or stop of heavy loads
Harmonic Distortion	A voltage or current waveform that assume as non-sinusoidal. It's due to multiple of power frequency that cause by arc furnace, rectifier, welding machine, and etc.
Voltage Fluctuation	Voltage amplitude modulated by low signal frequency such as 0-30Hz. Commonly cause by arc furnace and start-up or stop of motor.
Noise	Superimposed of high frequencies signal on the power system frequency waveform. Usually due to electromagnetic interferences.
Unbalance voltage	Three phase voltage that has voltage variation where the amplitude or phase angle are not equals. Usually cause by large load, and unbalance distribution of single phase loads in the system.

2.3 Voltage Sags

As shown in Fig. 2.1, the voltage sag is the reduction of the rms voltage at the certain period or certain cycle in a short period of time (Lamoree et al., 2010). In other word, voltage sag also be define as the voltage that were being supplied is not meet the requirement of the load and it can severely damage the load depend on the type of load that involve. The sudden drop of voltage could reach until 90% - 10% of nominal voltage (Fuad, 2007).

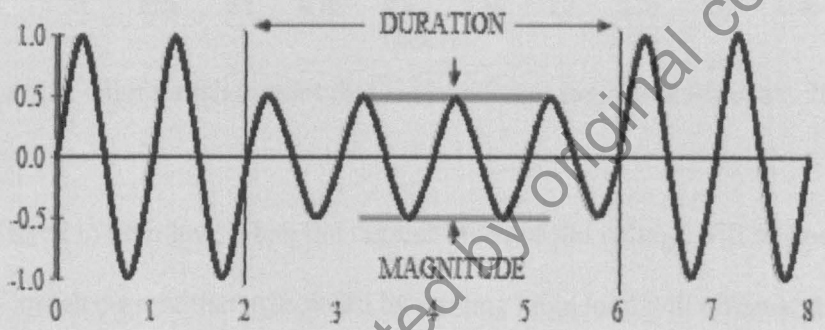

Figure 2.1: Voltage sags occurrence in power system (Sharma & Kaur, 2014).

2.3.1 Causes of Voltage Sags

The voltage sag commonly caused by internal source where from the facilities itself such as, starting a huge load or wiring problems. It also can caused by external source where the facilities are connected on the same line of the distribution network. Most researchers agree that the occurrence of voltage sag is heavily related to the occurrence of short circuit at the power supply. It is because the current rises as short circuit occurs which in turn causing large drop of voltage (Fuad, 2007). Fig. 2.2 shows one of the cause of voltage sags.

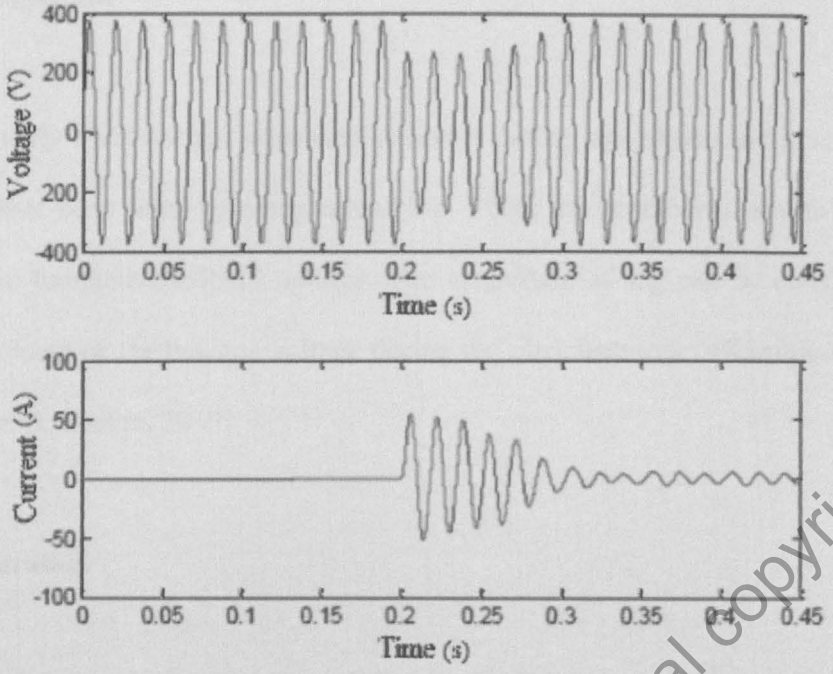

Figure 2.2: High inrush current that cause voltage sags (Ganesh et al., 2013).

Referred to ohm law, when the current increase the voltage will be decrease, so the flow of inrush current that associated by starting huge load will affected the voltage. Lightning strike also can cause a momentary voltage drop (Kamble & Thorat, 2014).

2.3.2 Characteristic of Voltage Sags

There are two important characteristic that can specify a voltage sag, which is duration and the RMS voltage. The reduction of voltage can be called voltage sag when the RMS voltage was drop at a power frequencies for a period of 0.5 cycle to one minutes. The drop of RMS voltage were called voltage sag when the voltage drop temporarily in between 10% to 90% of nominal voltage. Mostly voltage sag that occur do not lesser than 50% of its normal voltage and usually last from 3 to 10 cycles (Kamble & Thorat, 2014).

2.3.2.1 Magnitude

Usually RMS voltage were used to obtain the sag magnitude and it's a common approach that been used by many researcher. There also another alternative as peak voltage and fundamental RMS voltage. The magnitude of sag can be considered for residual voltage or the balance voltage during the circumstances. (Kamble & Thorat, 2014; Patne & Thakre, 2010).

2.3.2.2 Duration

The fault-clearing time will determine the duration of the voltage sag. The time duration of the voltage sag is the total time of the voltage magnitude below the voltage threshold. When the RMS voltage drop below the sag-starting voltage threshold, the time duration of voltage sag starts. When the RMS voltage recovered higher than the sag-ending threshold, the duration of voltage sag was ended (Kamble & Thorat, 2014).

2.3.3 Effect of Voltage Sags

Voltage sag or also being called a momentary power interruption has been a major issues among the industries that using a sensitive equipment in their production. The sudden drop of voltage could reach until 90 percent of voltage that should be supply to the appliance could damage some of important equipment. On other word, when the network power quality is bad, it will cause failure or damage the equipment and load that connected to the same line and the lifetime will be reduced (Yang et al., 2013).

2.4 Voltage Sags Referred To IEEE Standards

According to IEEE standard (IEEE Std 1159-2009), sag refer to decreasing of rms voltage in between 0.1 pu to 0.9 pu in a period of 0.5 cycle to 1 minute. Retained voltage and remaining voltage are the terminologies that are often in used in describing the variation of RMS value. In this practice, it is recommended to assume the sag value is the value of the remaining voltage. Therefore, an unspecified sag value will be assume as the remaining voltage. Duration of sag is not clearly defined as there are several opinions by previous researchers (Patne & Thakre, 2010). There are many researches state that period of sag is defined from 2 millisecond to several minutes. A voltage drop that less than 0.5 cycle cannot be defined effectively as variation in rms value. Definition of a very short period of sag occurrence is transient. There are three categories of sag duration that is instantaneous, momentary and temporary that coincide with the interruption. Voltage sag commonly caused by fault within the system however it is also can be caused by the starting of large motor or switching of a heavy load. In power quality community, the terms sag is commonly used for years to define a short period of undervoltages. Even the terms is not formally defined in The Authoritative Dictionary, it is accepted by various users (utilities, manufacturers, and end users) (IEEE Std 1159-2009). Table 2.2 shows categories and typical characteristic of short duration rms variations.

Table 2.2: Categories and characteristic of short duration rms variations (IEEE Std1159-2009).

Categories	Typical Duration	Typical Voltage Magnitude
1. Instantaneous		
• Sags	0.5 - 30 cycle	0.1 - 0.9 pu
• Swell	0.5 - 30 cycle	1.1 – 1.8 pu
2. Momentary		
• Interruption	0.5 cycle - 3 s	<0.1 pu
• Sags	30 cycle - 3 s	0.1 – 0.9 pu
• Swell	30 cycle - 3 s	1.1 – 1.4 pu
3. Temporary		
• Interruption	>3 s to 1 min	<0.1 pu
• Sags	>3 s to 1 min	0.1 – 0.9 pu
• Swell	>3 s to 1 min	1.1 – 1.2 pu

2.5 Solution for Voltage Sags

Voltage sag often occurs in industries and large commercial distribution system. However it cannot be discounted the fact that it also may occur in small and medium commercial if there is a motor is connected to the same network. The starting of motor results in voltage sag, however it is not enough to cause damages to facility equipment's (Lamoree et al., 2010). There are some methods used by researchers in order to mitigate the sudden drop of voltage. Some examples of methods are using DVR, SVC and D-STATCOM.