STUDY ON 6, 12 AND 24 PULSES D-STATCOM FOR VOLTAGE SAG MITIGATION

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ABSTRACT

In modern industrial nowadays, electric supply is crucial and brought major impact to economic and new technology development in the country. There are many issues and technical problems occur at distribution system. Voltage sag is one of major problems. In the distribution system, voltage sag can occur in any point at any time. This issue always brought up for discussion by Electrical power committee all around the world. There are many causes of voltage sag such as overload by consumption area, electrical faults on utility lines, switching operations, trip or short circuit and any single or three phase faults. In order to mitigate this problem, many research and power control have been used. Therefore, this project chooses the Distribution Static Compensator (DSTATCOM) for mitigating voltage sag that happens in power electrical area. Its ability to stabilize power distribution in network system and many useful characteristics is considered. DSTATCOM consists of two voltage level Voltage Source Converter (VSC), DC storage device and a coupling transformer. This project focuses on development of 6-pulses, 12-pulses and 24-pulses DSTATCOM in order to mitigate voltage sag and compared each DSTATCOM results to gain control of power distribution. In order to mitigate voltage sag, the D-STATCOM has been compared in terms of Voltage Per-Unit (Vpu) and reactive power compensations. In the end, the best design is chosen based on capability to mitigate voltage sag with most stable power distribution. It is proven that DSTATCOM able to mitigate voltage sag by injecting current so that voltage sag is back to its rated value. The voltage is restores during fault in order to improve power quality. All simulations results obtained using PSCAD/EMTDC software. By using DSTATCOM, it is able to give harmonic control and provide power quality solutions in utility and industrial applications.

ABSTRAK

Dalam industri moden sekarang, bekalan elektrik adalah penting dan membawa impak besar kepada pembangunan teknologi dan teknologi baru di negara ini. Terdapat banyak masalah dan masalah teknikal yang berlaku terhadap sistem pengedaran. Beban voltan adalah salah satu masalah utama. Dalam sistem pengedaran, bebanan voltan boleh berlaku pada bila-bila masa. Isu ini selalu dibawa untuk perbincangan oleh Majlis Jawatankuasa Elektrik Kuasa di seluruh dunia. Terdapat banyak punca bebanan voltan seperti bebanan sarat oleh kawasan penggunaan/konsumer, kerosakan elektrik di talian utiliti, penukaran talian operasi, litar pintas dan sebarang kerosakan satu fasa atau tiga fasa. Untuk mengurangkan masalah ini, banyak penyelidikan dan kawalan kuasa telah digunakan. Projek ini memilih Pemampas Statik(DSTATCOM) untuk mengelakkan beban voltan yang berlaku di kawasan elektrik kuasa. Keupayaannya ialah untuk menstabilkan pengagihan kuasa dalam sistem rangkaian dan banyak ciri berguna yang dipertimbangkan. DSTATCOM terdiri daripada dua tahap Penukar Sumber Voltan, peranti penyimpanan Arus terus(DC) dan transformer gandingan. Projek ini memberi tumpuan kepada reka bentuk 6-nadi, 12-nadi dan 24-nadi DSTATCOM untuk mengurangkan bebanan voltan dan membandingkan setiap keputusan DSTATCOM untuk menguasai pengedaran kuasa. Untuk mengurangkan bebanan voltan, reka bentuk akan dibandingkan dari segi Voltan Per-Unit (Vpu) dan pampasan kuasa reaktif. Akhirnya, reka bentuk terbaik akan dipilih berdasarkan keupayaan untuk mengurangkan bebanan voltan dengan pengagihan kuasa yang paling stabil. Dibuktikan bahawa DSTATCOM dapat mengurangkan bebanan voltan, dengan simulasi 6-denyut, 12-denyut dan 24-denyut DSTATCOM dalam persekitaran PSCAD / EMTDC. Voltan akan dikembalikan semasa kesalahan dan penghantaran kuasa dan kualiti diperbaiki. Semua keputusan simulasi yang diperoleh

menggunakan perisian PSCAD / EMTDC. Dengan menggunakan DSTATCOM, ia dapat memberikan pembetulan faktor kuasa, kawalan harmonik dan menyediakan penyelesaian kualiti kuasa dalam aplikasi utiliti dan perindustrian.

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LIST OF SYMBOLS AND ABBREVIATIONS

VSC	-	Voltage Source Converter
AC	-	Alternating Current
D	-	Derivative
DC	-	Direct Current
Vs	-	Voltage Source
Vi	-	Voltage Input
Ki	-	Integral Gain
Kp	-	Proportional Gain
PSCAD	-	Power System Computer-Aided Design
P	-	Proportional
PID	-	Proportional Integral Derivative Controller
PWM	-	Pulse Width Modulation
V	-	Volt
F	-	Frequency
D	-	Duty Cycle
R	-	Resistor
THD	-	Total Harmonic Distortion
GTO	-	Gate Turn-Off
MVAR	-	Mega Volt Ampere-Reactive
Hz	-	Hertz
PU	-	Per-unit
RMS	-	Root Mean Square
Vpu	-	Voltage Per-unit

CHAPTER 1

INTRODUCTION

1.1 Project Background

In modern industrial society nowadays, electricity is crucial and useful energy. Electrical power system is made up of components such as generators, lines, transformers, loads, switches and compensators. It consists of integration of generation, transmission, distribution and extended load area. Electric power systems are highly non-linear and complex networks with vast operational activities. It also takes account expected and unexpected disturbances affected the power system operation in input and output form [1]. This system is important as if it collapses, it would direct major impact nationally and globally also indirect impacts to economy and national security. With rapid development and increasing load demand throughout the country, it is possible to drive future needs if power generation remain constant. For this reason distributed power generations is receiving an attention of the researchers around the globe to be used in remote and rural areas [2]. A widely dispersed power sources and loads are the general configuration of modern power systems. Electric power systems can be divided into two main subsystems, namely, transmission systems and distribution systems. Transmission system function is to transfer electric power from electric generators to customer area, whereas a distribution system provides an ultimate link between high voltage transmission systems and consumer services. Super generator can supply important domestic or industrial loads during power shortages.

Common problems faced by customers is overloading in generator usage that affects efficiency generator and distribution quality [3]. Hence, improvement of power quality related to constraint occurred that needed to be analyse and familiar with. The problems of overloading, voltage variation and heating effects are very common. It takes a lot of time for its repair and involves lot of expenditure. In centralized national grid, such as local major power plant, one in Paka, Terengganu and another one under development in Pengerang, Rapid Project. The receiving subsystem is distribute into smaller region of each state in projected power as load demand required by each area [4].

There are multiple of subsystems in Malaysia that if the centralized national grid is unstable or under few constraints, microgrid should take over the electricity supply of distribution area until the main power system is back online. The Synchronous Static Compensator (STATCOM) based on Voltage Source Converter (VSC) is used for voltage regulation in transmission and distribution systems. The Distribution Synchronous Static Compensator, or DSTATCOM, used for regulates power flow problem in distribution system. The DSTATCOM can rapidly generate or absorb dynamic reactive power during system faults for voltage regulation. Strict requirements of DSTATCOM loss and total system loss penalty preclude the use of Pulse-Width Modulation (PWM) for DSTATCOM applications [5]. The commonly-implemented Phase-locked Loop (PLL) in the system, which is based on positive sequence bus voltage, unable response to dynamical changing of negative-sequence bus voltage due to system faults. In general, power compensation by DSTATCOM can have various functions such as elimination of power oscillation, elimination of harmonic current, etc. Under a balanced three-phase supply condition, some criteria must be met to optimize the overall system compensation. The research conducted by aimed to compensate the source current become purely sinusoidal and deliver the minimum average real power to the load. Although under non-linear load it can guarantee only one optimal criterion and in this project, objectives for power flow controller are proposed. In addition, Voltage Per-Unit(Vpu) correction of a protected load can be included in the control scheme by zeroing reactive power supplied by the source [6].

Increasing load demand requires more power generation which attract high usage of natural fuel such as coal and mines. Improvement on power plant and generation require more reliable and efficient power distribution. The development also increase the technology advancement which every person needed to charge smartphone or powerbank to ensure no more break from digital world. In case if any distribution fault happens, the suitable way of facing the problem is by incorporating Flexible AC Transmission System (FACTS) devices into the power flow. Facts devices such as Unified Power Flow Controller(UPFC), Static Compensator(STATCOM), Thyristor Series Controlled Capacitor(TCSC) and Static VAR Compensator are available in power distribution system and high load capacity building, with 11kV and above. These FACTS devices also needed maintenance and regular checkups so that the operation is under control. This project investigates regarding DSTATCOM performance in mitigating voltage sag. In many cases of power distribution problem, one of the major causes is voltage sag. It can happen by unbalance load or natural phenomena. In mitigating voltage sag, DSTATCOM is operated into power lines to compensate reactive power.

1.2 Problem Statement

Distribution lines are the important part in power system. In communications and electronics engineering, a distribution line is a specialized cable or other structure designed to distribute alternating current or radio frequency, that is, currents with frequency high enough that their wave nature must be taken consideration. In order to transmit power to load, decrement of power quality affect the efficiency of power in distribution line. This is caused by size of load whether it is inductive or capacitive. Examples of power quality issues are voltage surge, spike voltage or transients, electrical noise that involves disturbances between supply and neutral, voltage sag, overload consumer area and under voltage due to peak demand.

Most of these issues results to voltage sag [7]. Voltage sag effects on end user or customer to any electrical appliances and electronic devices. In industrial area, heavy machinery and equipment reduce span time if always expose to voltage sag. Due to technology in modern world, there are many high end technology and electronic devices use commercially that always need charging and discharging. This causes unbalance in load area that affect performance of power distribution. This is also main causes of power distribution problem due to voltage sag.

The issues brought up here is voltage sag. Common problem in distribution line is due to voltage sag occurred by Single Line to Ground (SLG) Fault and Three phase fault. In power system, Flexible AC Transmission System (FACTS) devices and custom power technology has the ability to overcome the problem. One of FACTS devices, that is DSTATCOM, is implied to mitigate the issue of power loss and low distribution quality [5]. This research focused on mitigating voltage sag and poor power distribution by compensation in reactive power. In order to mitigate voltage sag, few designs been made, that is 6-pulses, 12-pulses and 24-pulses DSTATCOM.

1.3 Project Objectives

The aim of this project consists of four main objectives:

(i) To develop DSTATCOM for distribution system using PSCAD software in order to mitigate voltage sag.

(ii) To simulate 6, 12 and 24-pulses of DSTATCOM for reactive power control in order to compensate power distribution.

(iii) To understand the design under single line fault and three phase fault for voltage sag problem.

1.4 Scope of the Project

As this project aims to mitigate voltage sag at distribution line system by using DSTATCOM, it then consists of two major works, designing the configuration and controls strategies. The simulation model are developed using PSCAD software. This project is limited to the following scopes:

(i) The analysis focused on effectiveness of power flow controller of 6-pulses 12-pulses and 24-pulses DSTATCOM.

(ii) The load rating is 100 MVA.

(iii) STATCOM is connected to 115kV distribution line using 2kV/115kV transformer.

(iv) The types of fault in this project are Single Phase Fault and Three Phase Fault.

(v) All the design and simulations under PSCAD environment.

1.5 Report organization

This report is orderly consists into 5 chapters. The content of each chapter explained briefly below.

Chapter 2: discuss power quality problem that is voltage sag in distribution system. DSTATCOM theory is also discuss detail in its basic operation, configuration and functions.

Chapter 3: present on the methodology that used to construct this project. The details of layout configuration for each DSTATCOM is presented.

Chapter 4: covers the result and discussion finding that being used in the case study.

Chapter 5: summarizes the whole report and future recommendation.

CHAPTER 2

LITERATURE REVIEW

This chapter elaborate on Distribution line system, Power quality issues and DSTATCOM. A power system with compensation on voltage and reactive power supplies power with good quality consumption. Power system control involve control of power production and supply to consumer area. The transmission and distribution line system involve many types of power quality issues. Voltage Sag is one of the issues that identified to compensate. Compensation on reactive power able to mitigate voltage sag. DSTATCOM is one of FACTS devices that able to mitigate voltage sag. The DSTATCOM configuration and controller design is elaborated in this chapter.

2.1 Electric Power System

There are many ways to generate electricity. Various sources also available for electricity generation. Generation of electric power using the form of energy such as coal and diesel. Windpower and turbine also generates electric power. Electrical network involved components electrical for supply deployment, energy transfer and distribution for consumerization. The distribution system is the last station that starts from generation links to substations. The three major components in power system consists of generation, high voltage transmission grid and distribution system.

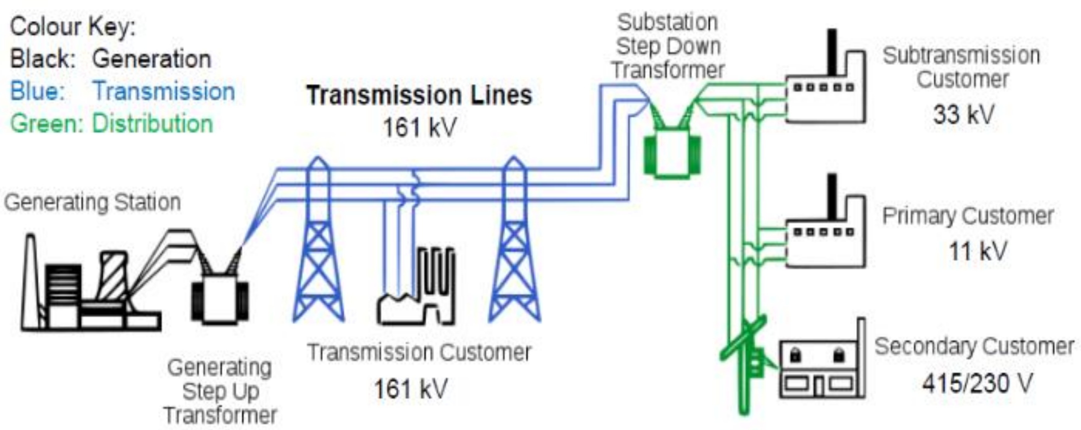

Figure 2.1: The figure by Solo Nunoo (Apr 2011) shows Electric Power System in Ghana [8]

Electric power is distributed in bulk from generation plant to transmission plant. The distribution substation receives the energy supply from transmission plant then, it is distribute to end consumers. Primarily driven by heat engines fueled by combustion Electricity is mostly generated at power plant by electromechanical generators, primarily driven by heat engines fueled by combustion. Three major electricity sources are fossil fuels, nuclear energy and renewable energy sources [7]. This form of primary energy is converted to another form of energy, that is electricity. The process is called generation of electric power.

2.1.1 Electric Power Transmission

Electric power transmission is the bulk movement of electrical energy from a generating site to an electrical substation. The interconnected lines which facilitate this movement is known as a transmission network.

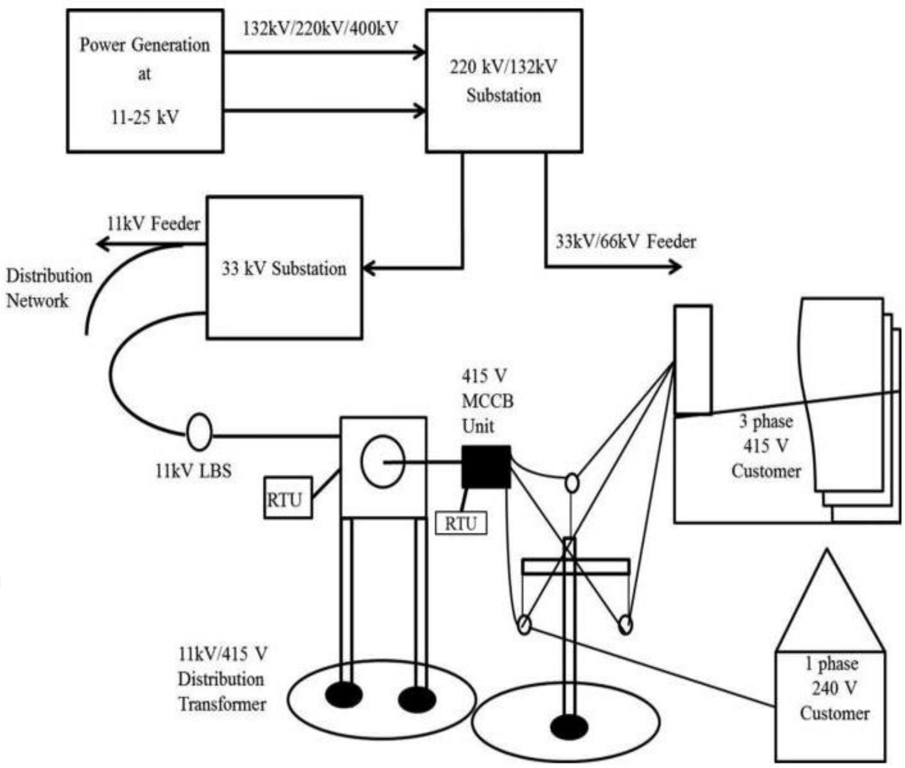

Figure 2.2: The figure by Sanket Goel (May 2016) shows Indian Transmission and Distribution Network [9]

Specifically, it is the bulk transfer of electrical power from power plant to substations near populated areas. Electricity is transmitted at high voltages, that is 135kV or above, to reduce energy losses which occurs in long-distance transmission. It is because the higher the voltage, the lower the current is and the resistance losses in conductor is lower [3].

2.12 Electric Power Distribution

Electric power distribution is the final stage in the delivery of electric power. The system carries electricity from the transmission system to individual consumers. The transmission voltage ranging from 115kV be lower by step down transformer to medium voltage ranging between 2kV to 35kV for distribution. The substation near populated area step down this voltage fit with utility voltage used by household appliances, industrial equipment and machineries[2].

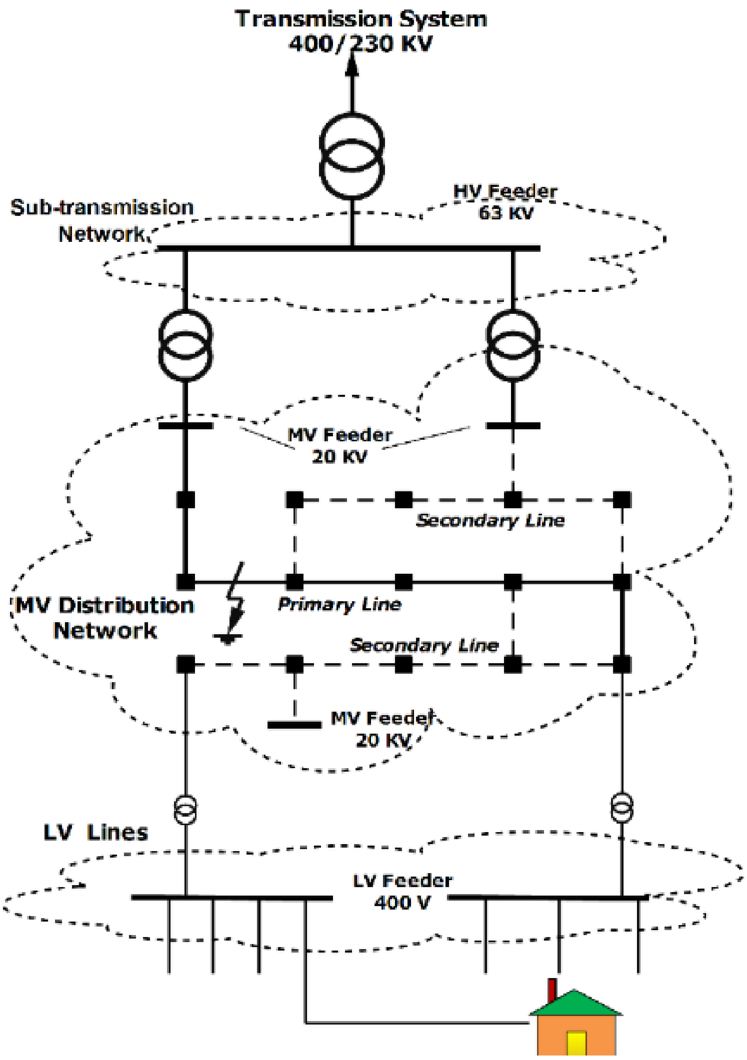

Figure 2.3: The figure from Iman Zabet (July 2010) shows Power Distribution Network Layout, relating to subtransmission network and low-voltage distribution lines [10]

Distribution of electric power is process of delivering electricity to customers over transmission and distribution power lines. Nowadays, due to increasing population area and power grid, there are many issues regarding quality of power distribution. There are substations that are decades, and the existing grid as years goes by, it is decrease its efficiency and reliability. Climate issues and weather also causes of destruction and outages. Maintenance and surveillance is important in this area so that consumer end is not affected by power quality issues [11]. Voltage stability problems is common in electric power distribution. In this project, the design is distribution line with voltage 115kV to be lower by step down transformers for simulation.

2.2 Power Quality Issues

There are Power Quality Issues that causes voltage sag in distribution system. Main quality issues related to power sharing in power system is overload. To satisfy load demand instantaneously, power generation may exceeds requirement caused by frequency fluctuates from synchronous generator or switching activities. Power failure is a short or long term loss of electric power to an area mostly cause by short circuit, damage to electric transmission line, overvoltage, faults at power stations and more commonly failure due to overloading [3]. The possible damage areas are affected by losing power. The one inherent problem with standard power sharing and monitoring units is their broadcast strength. In order to prevent overload, new control strategy is to implement that automatically controls overload on a generator by sharing power and cut off supply once the power consumption exceeds the amount of power supplied. However, the main aim of the work is to provide a non-interrupted power supply to the energy consumers. By implementation of this scheme the problem of interruption of supply due to generator overloading is unavoidable by means that the sag voltage is still able to surface if there is any fault happens [4].

2.2.1 Voltage Sag

Voltage sag commonly faced all around the world. In transmission system or distribution network, voltage sag is common issue and cause many industrial and commercial loads breakdown. If the voltage sag exceeds a few cycle, motors, robots, servo drives and commercial loads cannot maintain control of the process.

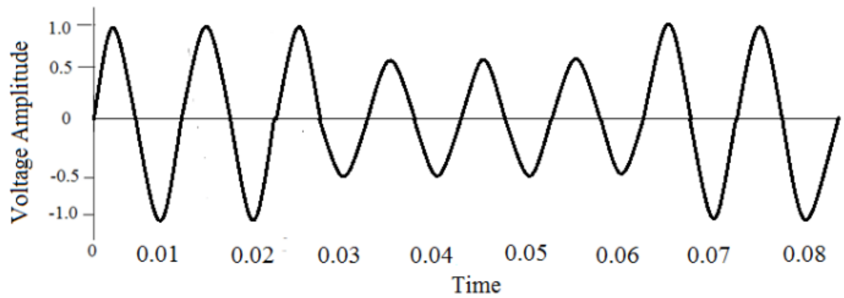

Figure 2.4 : The figure from A. K. Akella (Jan 2015) shows Typical Waveform during Voltage sag [12]

Voltage sag definition is a decrease of root mean square (RMS) voltage from 0.1 to 0.9 per unit (PU), for a duration of 0.5 cycle to 1 minute. There are many causes of voltage sag, such as lightning strikes that cause overload at any specific point, heavy load switching that cause unbalance load consumption, transformer energizing and any faults in the system [6].

2.2.2 Sources of Voltage Sag

There are three main sources of voltage sags. One of the causes is starting of large motor loads either on the affected site or by a consumer on the same circuit. Secondly, it may also originated by the faults on other branches of the supply network. Thirdly, it might because of the faults in the internal supply scheme of the consumer's installation. Voltage sags noticed on the supply network is primarily originated by the electric short circuit on the electrical supply system. The impact of

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