



AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electrical Power and Machines Engineering

# Operation of Multi-Terminal HVDC System

A Thesis submitted in partial fulfilment of the requirements for the degree of

Master of Science in Electrical Engineering

(Electrical Power and Machines Engineering)

by

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Bachelor of Science In Electrical Engineering

(Electrical Power and Machines Engineering)

Faculty of Engineering, Ain Shams University, 2012

Supervised By

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Date:29 June 2019



# Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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# Abstract

The interconnection between different grids is adopted as one of the economical solutions for electricity adequacy rather than spending on expansion which may be needed only for few hours per day. This became as common practice between neighbouring countries for power exchange during peak hours especially when there is time shift between these peak periods in the interconnected countries. If the interconnected networks have different frequencies such as Saudi Arabia with Yemen, Norway with Germany and Kingdom of Saudi Arabia with Egypt, the High Voltage Direct Current HVDC transmission become the only feasible solution to realize this objective. The HVDC system not only enables connecting two networks with different frequencies but also privileged with easier load flow control and possibility of multi-terminal connection.

Recently, Egypt and Kingdom of Saudi Arabia are planning for interconnection. Egypt is one of pioneer countries in generating wind energy where Zaafrana and Gabal Elzeet areas are rich with wind nature and speed where wind farms were constructed and operated with high potential for expansion. These interests inspired more research in operation and analysis of multi-terminal HVDC system.

In this thesis, a three terminal VSC HVDC system model is simulated by PSCAD/EMTDC and Matlab-Simulink software package. One terminal is used to control the DC voltage all over the network and act as a slack bus to handle the system losses. While, the other two VSC stations are used to control the power flow between the stations in both directions. Two different network topologies (Radial and Mesh) are simulated. The control strategy that used is vector control. The vector control strategy and pulse width modulation technique are used in the model. Three different cases are conducted; the first one is a normal operation. The second is studying the effect of changing the dc capacitor size on the network DC voltage. The third is studying the effect of changing the gain of the PI controller of the DC voltage in terms of dynamic and steady state responses. A ballistic DC C.B is used for protection discrimination device with a new robust controller. A pole to ground fault is simulated by Matlab-Simulink and good results are obtained.

**Key words:**

HVDC, VSC-HVDC, Multi-Terminal HVDC PSCAD/EMTDC, Faults, DC C.B, Matlab-Simulink and AC/DC power flow.

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# Table of Contents

ABSTRACT

ACKNOWLEDGEMENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS and ABBREVIATIONS

CHAPTER I INTRODUCTION

1. Background and Introduction
  - 1.1. Historical Background
  - 1.2. Thesis Motivation
  - 1.3. Literature Review
    - 1.3.1. Thesis Objectives
  - 1.4. Thesis Outlines

CHAPTER II

HVDC TRANSMISSION SYSTEM

2. Conventional (LCC) and (VSC) HVDC Systems
  - 2.1. Background
  - 2.2. Different Configurations of HVDC Systems
    - 2.2.1. Mono polar HVDC System
    - 2.2.2. Bi polar HVDC System
    - 2.2.3. Back to Back HVDC System
    - 2.2.4. Multi Terminal HVDC System
  - 2.3. Comparison between LCC and VSC HVDC Systems
    - 2.3.1. Line Commutated Converter (LCC) based HVDC
    - 2.3.2. Voltage Source Converter (VSC) based HVDC
      - 2.3.2.1. Different VSC Configurations

CHAPTER III

3. MATHEMATICAL MODELLING FOR MULTI TERMINAL VSC BASED HVDC
  - 3.1. Basic Two Terminal VSC HVDC System
    - 3.1.1. Basic Model Configuration

- 3.1.2. Model Mathematical Representation
- 3.2. Multi Terminal VSC HVDC Systems
  - 3.2.1. Operation Principles
  - 3.2.2. Control Strategy
    - 3.2.2.1. Vector Control
    - 3.2.2.2. Inner Current Controller
    - 3.2.2.3. Outer Loop Controllers
      - 3.2.2.3.1. DC Voltage Control
      - 3.2.2.3.2. Active Power Control
      - 3.2.2.3.3. Reactive Power Control
      - 3.2.2.3.4. AC Voltage Control
  - 3.2.3. DC Faults
    - 3.2.3.1. VSC Cable DC Pole-to-Ground Fault Analysis
    - 3.2.3.2. Design of DC Circuit Breaker (Ballistic C.B)

## CHAPTER IV

### SIMULATION RESULTS

#### 4. Simulation Results

- 4.1. System Description
- 4.2. Active Power Control
  - 4.2.1. Different Normal Operation Case studies
- 4.3. DC Fault Current C/CT's in MTDC VSC HVDC Systems

## CHAPTER V

### CONCLUSION AND FUTURE WORK

- 5.1. Conclusion
- 5.2. Future Work

### BIBLIOGRAPHY



# List of Figures

FIGURE	PAGE
2.1	COST VS DISTANCE CRITERION ..... 30
2.2	DIFFERENT HVDC CONFIGURATIONS ..... 32
2.3	GRAETZ BRIDGE FOR LCC BASED HVDC SYSTEM ..... 33
2.4	TWO TERMINALS LCC BASED HVDC SYSTEM ..... 34
2.5	THREE PHASE TWO LEVEL VSC BASED HVDC SYSTEM ..... 35
2.6 (A)	PULSE WIDTH MODULATION, TWO LEVEL CONVERTER ..... 36
2.6 (B)	PULSE WIDTH MODULATION, THREE LEVEL CONVERTER ..... 36
2.6 (C)	PULSE WIDTH MODULATION, MODULAR MULTI LEVEL CONVERTER.. 36
2.7	THREE LEVEL NEUTRAL POINT CLAMPED (NPC) VSC TOPOLOGY .... 37
2.8	MODULAR MULTI LEVEL VSC TOPOLOGY ..... 37
3.1	TWO TERMINALS VSC BASED HVDC SYSTEM ..... 40
3.2	VSC STATION CONNECTED TO AN AC SYSTEM ..... 41
3.3	VSC STATION CONNECTED TO AN AC SYSTEM (DETAILED MODEL)... 42
3.4	THREE TERMINALS VSC BASED HVDC RADIAL SYSTEM ..... 44
3.5	SIMPLIFIED STRUCTURE OF A VSC STATION CONTROLLER ..... 45
3.6	INNER CURRENT CONTROLLER SCHEMATIC DIAGRAM ..... 47
3.7	PI CONTROLLER OF DC VOLTAGE (VDC) ..... 48
3.8	DC VOLTAGE CONTROL WITH 400 KV REFERENCE SIGNAL ..... 49
3.9	PI CONTROLLER OF ACTIVE POWER (P) ..... 49
3.10	STEP RESPONSE OF P AND RELEVANT RESPONSE OF PI CONTROLLER... 50
3.11	PI CONTROLLER OF REACTIVE POWER (Q) ..... 51
3.12	TWO LEVEL TOPOLOGY VSC HVDC SYSTEM .....52
3.13	VSC STATION WITH POLE TO GROUND FAULT .....53
3.14	CIRCUIT REPRESENTATION FOR CAPACITOR DISCHARGE STAGE .....54
3.15	CIRCUIT REPRESENTATION FOR GRID-SIDE FEEDING STAGE .....54
3.16	FEEDER CURRENT COMPOSITION OF BOTH CAPACITOR AND AC GRID CURRENTS.....54
3.17	BALLISTIC CIRCUIT BREAKER SIMULINK CONTROLLER MODEL.....55
3.18	CONTROLLER DESIGN OF BALLISTIC DC C.B.....56
3.19	SEQUENCE OF ADDING RESISTANCES WITH A PREDEFINED TIME STEP ..56
3.20	DC CURRENT DECAYING TILL ZERO CROSSING WHILE ADDING RESISTANCES (R)..57
4.1	RADIAL NETWORK OF THREE TERMINALS VSC STATIONS ..... 59
4.2	RADIAL NETWORK POWER FLOW OF UNDER DIFFERENT SCENARIOS WITH DC SIDE C=300 MICRO F ..... 62
4.3	MESH NETWORK OF THREE TERMINALS VSC STATIONS ..... 62
4.4	MESH NETWORK POWER FLOW UNDER DIFFERENT SCENARIOS WITH DC SIDE C=800 MICRO F ..... 64
4.5	EFFECT OF PI TUNING ON DC VOLTAGE OVER THE NETWORK ..... 65
4.6	THREE TERMINALS VSC HVDC NETWORK (RADIAL NETWORK).....66
4.7 (A)	POWER FLOW THROUGH THE RADIAL NETWORK AT NORMAL OPERATION .....68

4.7 (B)	SCHEMATIC DIAGRAM FOR THREE TERMINALS RADIAL CONNECTED AT NORMAL OPERATION.....	68
4.8	VOLTAGE, CURRENT AND POWER OF VSC1, AT NORMAL OPERATION (RADIAL NETWORK).....	70
4.9	VOLTAGE, CURRENT AND POWER OF VSC2, AT NORMAL OPERATION (RADIAL NETWORK).....	71
4.10	VOLTAGE, CURRENT AND POWER OF VSC3, AT NORMAL OPERATION (RADIAL NETWORK).....	72
4.11(a)	POWER FLOW THROUGH THE NETWORK AT FAULT WITHOUT C.B ACTIVATED.....	73
4.11 (B)	SCHEMATIC FOR THREE TERMINALS SYSTEM RADIAL CONNECTED UNDER FAULT....	73
4.12	VOLTAGE, CURRENT AND POWER OF VSC1, AT FAULT CONDITION WITHOUT C.B ACTIVATED.....	75
4.13	VOLTAGE, CURRENT AND POWER OF VSC2, AT FAULT CONDITION WITHOUT C.B ACTIVATED.....	76
4.14	VOLTAGE, CURRENT AND POWER OF VSC3, AT FAULT CONDITION WITHOUT C.B ACTIVATED.....	77
4.15	POWER FLOW THROUGH THE NETWORK AT FAULT WITH C.B ACTIVATED .....	78
4.16	VOLTAGE, CURRENT AND POWER OF VSC1, AT FAULT CONDITION WITH C.B ACTIVATED.....	80
4.17	VOLTAGE, CURRENT AND POWER OF VSC2, AT FAULT CONDITION WITH C.B ACTIVATED.....	81
4.18	VOLTAGE, CURRENT AND POWER OF VSC3, AT FAULT CONDITION WITH C.B ACTIVATED.....	82
4.19	THREE TERMINALS VSC HVDC NETWORK (MESH NETWORK).....	83
4.20 (a)	POWER FLOW THROUGH THE MESH NETWORK AT NORMAL OPERATION.....	85
4.20 (b)	Schematic diagram for Three terminals mesh connected topology.....	85
4.21	VOLTAGE, CURRENT AND POWER OF VSC1, AT NORMAL OPERATION (MESH NETWORK).....	86
4.22	VOLTAGE, CURRENT AND POWER OF VSC2, AT NORMAL OPERATION (MESH NETWORK).....	87
4.23	VOLTAGE, CURRENT AND POWER OF VSC3, AT NORMAL OPERATION (MESH NETWORK).....	88
4.24 (a)	POWER FLOW THROUGH THE NETWORK AT FAULT WITHOUT C.B ACTIVATED.....	89
4.24 (b)	Schematic diagram for Three terminals mesh connected topology under fault....	89
4.25	VOLTAGE, CURRENT AND POWER OF VSC1, AT FAULT CONDITION WITHOUT C.B ACTIVATED (MESH-NETWORK).....	90
4.26	VOLTAGE, CURRENT AND POWER OF VSC2, AT FAULT CONDITION WITHOUT C.B ACTIVATED (MESH-NETWORK).....	91
4.27	VOLTAGE, CURRENT AND POWER OF VSC3, AT FAULT CONDITION WITHOUT C.B ACTIVATED (MESH-NETWORK).....	92
4.28	VOLTAGE, CURRENT AND POWER OF VSC3, AT FAULT CONDITION WITHOUT C.B ACTIVATED (MESH-NETWORK) ZOOM VIEW.....	93
4.29	DC CURRENT OF C.B 5 (TO THE LEFT) AND C.B 6 (TO THE RIGHT).....	93