RECENT ADVANCES IN HIGH-VOLTAGE DIRECT-CURRENT POWER TRANSMISSION SYSTEM

K. Pawani, RIT, Raipur, Pawani60_pantnaik@yahoo.co.in[1]; Sachidanand Ojha, Mahatma Gandhi Chitrakoot Gramodaya Viswavidyalaya Chitrakoot, satna (M.P), sd_ojha@yahoo.co.in [2]; Rama Mishra, M.E IVsem, RIT, Raipur, mishrarama02@gmail.com[3]

Abstract

The ever increasing progress of high-voltage high-power fully-controlled semiconductor technology continue to have a significant impact on the development of advance power electronic apparatus used to support optimized operation and efficient management of electrical grids, which in many cases are fully or partially deregulated networks. Developments advance both the high voltage direct-current (HVDC) power transmission and the flexibility alternating current transmission system (FACTS) technologies. In this paper, an overview of the recent advances in the area of voltage source converter (VSC) HVDC technology is provided. Selected key multilevel converter topologies are presented. Control & modeling method are discussed. It is confirmed that the continuous development of power electronics present cost effective opportunities for the utilities to exploit and HVDC remains a key technology. In particular, VSC-HVDC can address not only conventional network issues such as bulk power transmission, asynchronous network interconnection, back-to-back AC system linking and voltage/stability support to mention a few, but also niche markets such as the integration of large scale renewable energy sources with the grid.

Introduction

The fully-controlled semiconductor devices available today for high-voltage high power converter can be either thyristor or transistors. These device can be used for a VSC with pulse-width modulation (PWM), operating at frequencies higher than the line frequency and self-commuted via gate pulse.

HVDC and FACTS system are important technologies, supporting in their own way the modern power system, which in many cases are fully partially deregulated in several countries. In near future, even higher integration of electrical grids and marked driven development are expected as, for instance, countries in the Middle-east, China, India and South America require infrastructure to power their growth.

Today, there are more than 92 HVDC projects worldwide transmitting more than 75GW of power employing two distinct technologies as follows

1. Line-commutated current-source converters (CSCs) using thyristor. This technology is well established for high power, typically around 1000MW, with the largest project being the Itaipu system in system in Brazil at 6300MW power level.

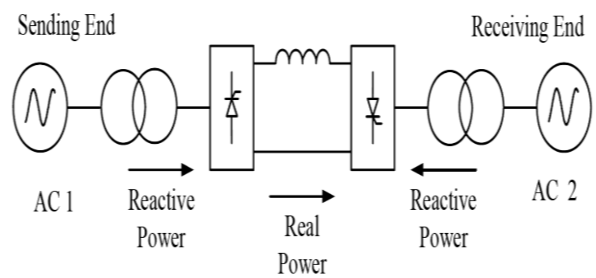

Figure 1: HVDC system based on CSC technology with thyristors

2. Forced-commutated voltage-source converter(VSCs) using gate-turn-off thyristor (GTOs) or in most industrial cases insulated gate bipolar transistor(GTOs) or in most industrial cases insulated gate bipolar transistors(IGBTs). It is well established technology for medium power levels thus far, with the largest size project being the latest size project being the latest one named Estlink at 350 MW level.

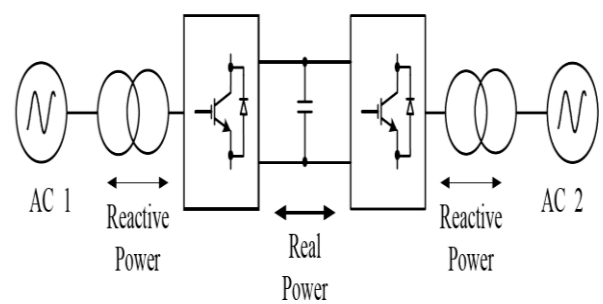

Figure 2: HVDC system based on VSC technology built with IGBTs.

3. The objective of this paper is to provide an overview of the HVDC technologies. Modeling and control in another area of importance and recent contribution presented in the technical literature are analyzed briefly. Finally, emerging application of VSC-HVDC system and multi-terminal DC configuration that can be used to interconnect large scale wind energy sources with the grid discussed.

HVDC System Configuration

Depending upon the function and location of the converter stations, various configurations of HVDC configuration but similar type of configuration but similar type of configuration exist for VSC-HVDC with or without transformers depending upon the project in question.

A. Back-to-Back HVDC system

In this case, the two converter station is located at same site and there in no transmission of power with a DC link over a long distance. The two AC system interconnected may have the same or different frequency.

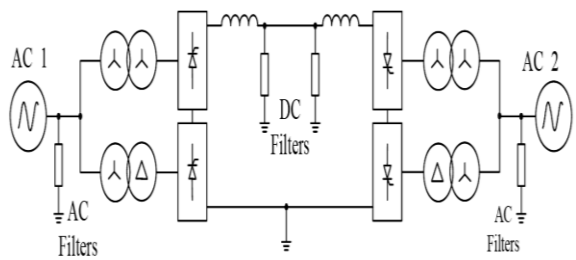

Figure 3: Back-to-back CSC-HVDC system with 12-pulse converters.

B. Monopolar HVDC System

In this Configuration, two converter are used which are separated by a single pole line and a positive or a negative DC voltage is used,Many of the cable transmission with submarine connection use monopolar system. The ground in used to return current.

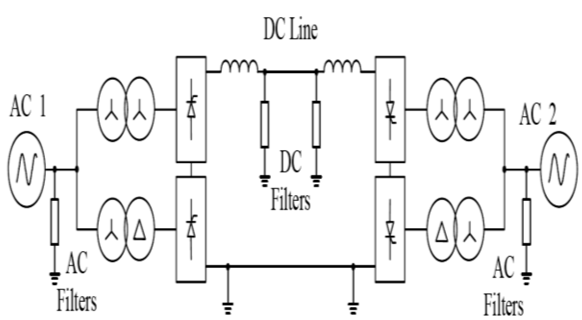

Figure 4: Monopoolar CSC-HVDC system with 12 pulse converters.

C. Bipolar HVDC System.

This is the most used configuration of a CSC-HVDC system in application where overhead lines are used to transmit power. In fact, the bipolar system is two monopolar system.

The advantage of such system is that one pole can continue to transmit power in the case that the other one is out of service for whatever reason. In other words, each system can operate on its own as an independent system with earth return.

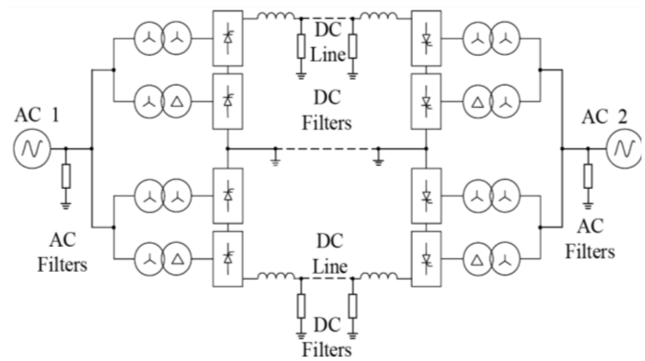

Figure 5: Bipolar CSC-HVDC system with one 12-pulse converter per pole.

D. Multi-terminal HVDC system

In this configuration there are more than two sets of converter like the bipolar version. In this converter 1 and 3 can operates as rectifier while converter 2 operates as inverter. Working in other order, converter 2.

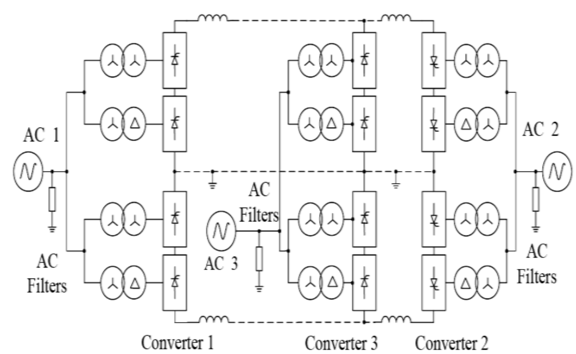

Figure 6: Multi-terminal CSC-HVDC system parallel connected.

VSC-HVDC Fundamental Concepts

A basic VSC-HVDC system comprises of two converter station built with VSC topologies. Typically, many series connected IGBT are used for each semiconductor. In order to deliver a higher blocking voltage capability for the converter and therefore increase the DC bus voltage level of the converter and therefore increase the DC bus voltage of the HVDC system.

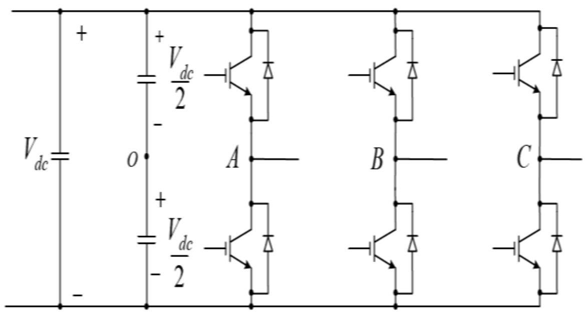

Figure 7: Conventional two-level VSC three-phase topology.

The converter is typically controlled through sinusoidal PWM (SPWM) and the harmonics are directly associated with the switching frequency of each converter. Filter are also include on the AC side to further reduce the harmonics content flowing into the AC SYSTEM.

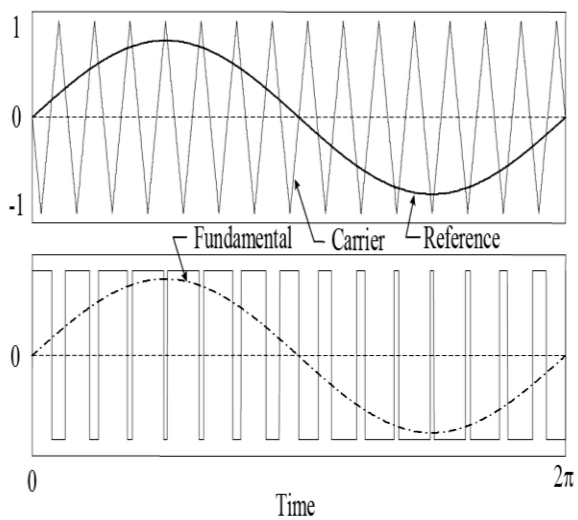

Figure 8: Tow-level sinusoidal PWM method: reference (sinusoidal) and carrier (triangular) signals and line-to-neutral voltage waveform.

The use of VSC as opposed to a line commutated CSC offer the following advantage

- Avoidance of commutation failures due to disturbance in the AC network.
- Possibility to connected the VSC-HVDC system to a "weak" AC network or even to one where no generation source is available and naturally the short-circuit level is very low.
- No need of transformer for the conversion process.

Multilevel VSC Topologies For HVDC

In this section, different selected VSC topologies suitable for the implementation of a VSC-HVDC system are discussed. Multilevel converter extend the well-known advantage of low and medium power PWM converter technology into the high power application suitable for high-power adjustable speed drive and large converter for power system through FACTS and VSC-based HVDC power transmission.

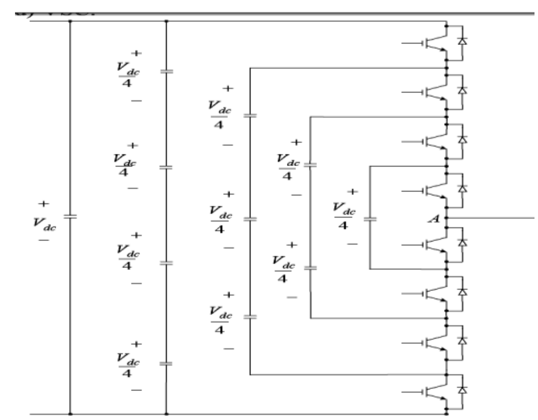

Figure 9: Five- level flying capacitor VSC phase leg topology

Modelling And Control

Recently, a dynamic model for a back-to-back HVDC system based on the three-level NPC topology was presented, Finally, in a control system for the VSC-HVDC during island operation and under three-phase balanced fault was investigated and it has been found that current limit of the converter s has a significant influence on the dynamic response of the system.

Emerging Applications

VSC –HVDC can be effectively used in a number of key areas as follows

- Power supply to island.
- Remote small-scale generation
- Off-shore generation and deep sea crossing
- Multi-terminal systems.

From the technology point of view, wind farm and off-shore wind farms in particular are well-suited for VSC-HVDC application.

VSC-HVDC Worldwide Installation

In this section, the various projects worldwide where VSC-based HVDC systems have been successfully exploited are discussed. They involve Back-to-back system (Eagle pass, USA), wind energy application (Gotland, Sweden), Power enhancement (Crosssound link, USA). It should be noted that the DC voltage has reached ±150KV and the largest system is at 350MW, making the VSC-HVDC a well established technology in the medium power levels.

Conclusion

In this paper, advances of the VSC-HVDC technology are presented. the key benefits include independent control of active and reactive power through the PWM control of the converter. It is confirmed that development associated with VSC-HVDC technologies have deliver system at voltage level up to ±150kv and power level up to 350MW.

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