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A REVIEW ON VOLTAGE CONTROL OF MULTI TERMINAL VSC-HVDC TRANSMISSION SYSTEM FOR OFFSHORE WIND POWER PLANT

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ABSTRACT- This paper deals with multiterminal voltage source converter (VSC) HVDC transmission systems for the connection of offshore wind power plants to the main land ac grid. A droop-based control scheme is considered. The droop controllers have been designed base on a mixed sensitivity model by tackling a curved improvement issue with straight network imbalances. The framework is broke down through recreations and tentatively in a scaled stage. Recreations show the control execution during a breeze speed change and a voltage hang in the principal ac network. Test results include wind power changes (increase and decrease) and an eventual VSC loss (both considering grid-side and wind farm VSC loss). In all the cases, the simulation and the experimental results have shown a good system performance.

Keywords- voltage source inverter, cascade H bridge multilevel inverter, shunt active filter.

I. INTRODUCTION

Demand of electricity is ever increasing. Over the past decades, the increment in electricity demand has been largely balanced by capacity development of conventional generations. However, further capacity development of these generations to balance demand of electricity is considered unsustainable mainly due to limited resource of their primary energies and due to negative impacts they introduce to the environment. In order to meet the future demand of electricity as well as to replace ageing existing generations, a number of new generation technologies i.e. wind power, solar thermal, solar photovoltaic, biomass, biodiesel, tidal power and wave power, which utilize the environmentally friendly power assets for example wind, sun based, biomass, biodiesel, flowing and wave energy as their essential energy, have been created. Wind power innovation changes dynamic energy in wind speed into power by using various breeze turbines. These breeze turbines are installed in a particular area where the potency of wind energy is high and are linked together forming a wind power plant (WPP). In Europe, development of WPPs for electricity generation has been growing in past years and is expected to continue in the near future. At present, contribution of WPPs to electricity generation only covers a small percentage of the load. These WPPs are installed onshore and offshore close to the shore (less than 60 km). In the future, it is foreseen that a number of large capacity WPPs would be installed further offshore (more than 60 km) where high potency of wind energy and large space are available.

In order to integrate the future far offshore WPPs into the onshore grid, long cable transmission would be required. Moreover, regarding the capacity of these WPPs, large transmission capacity would be required. However, variability of the wind speed and thus variability of the power generated by WPPs would result in a relatively low capacity factor of thetransmission and thus relatively high transmission cost peramount of energy delivered. The capacity factor can be increased if the transmission connects several offshore WPPs. Moreover, if the transmission is extended further, it may be used to facilitate power trading between countries in addition to evacuate power from the WPP. If these solutions were applied, several far offshore WPPs would be connected to multiple onshore grids and thus it would lead to the development of a transnational offshore network.For such a multi-terminal offshore network, where large power would be transmitted overlong distance, application of high-voltage alternating-current transmission (HVAC) technology may be difficult to implement due to large amount of reactive power compensation required. Thus, an alternative is to use high- voltage direct-current transmission (HVDC) technology. Moreover, since the offshore network may act as a power pool where power may be injected to and extracted from the network at different nodes, flexibility to control direction of power whilst maintaining voltage in the network is required. For such a situation, implementation of voltage sourced converter HVDC (VSC-HVDC) technology is favourable.

VSC-HVDC is capable of changing the direction of power whilst maintaining voltage in the dc network. Moreover, it is capable of performing independent active and reactive power control and of operating without necessarily depends on communication between the converters. Furthermore, since it is self commutated, it is inherently capable of providing self restoration as well as providing black start for the connected grid or the connected offshore installation. In addition, it introduces a compact converter

II. PROBLEM DEFINITION

An important topic of discussion related to offshore wind generation is the transmission system. An offshore wind farm can be connected to the main ac grid using transmission systems based on ac or dc technology .The choice between these technologies depends on the cost of the installation which depends, in turn, on the transmission distance and power. The need to compensate for the impedance of the lines in ac transmission makes its price grow with the distance at a higher rate than dc transmission, though dc transmission infers a high fixed cost because of the need of enormous power converters. Consequently, there is an earn back the original investment distance from which the dc choices becomes lower estimated than ac Until as of late, HVDC, transmission frameworks depended on current-took care of line-commutated converters. New converter geographies and lower evaluated quick exchanging semiconductors have recently made it possible to build voltage source converter (VSC)-based HVDC transmission systems. The benefits of using VSC and fast switching are the ability to independently control the active and reactive power while reducing the size of the output filters needed to have a low harmonic distortion.

III.VSC-HVDCFUNDAMENTA CONCEPTS

A basic VSC-HVdc system comprises of two converter stations built with VSC topologies. Typically, many series-connected IGBTs are used for each semiconductor in order to deliver a higher blocking voltage capability for the converter, and therefore in-crease the dc bus voltage level of the HVdc system. It should be noted that an antiparallel diode is also needed in order to ensure the four- quadrant operation of the converter. The dc bus capacitor provides the required storage of the energy so that the power flow can be controlled and offers filtering for the dc harmonics. The VSC-HVdc system can also be built with other VSC topologies. Key topologies are presented in Section

The converter is typically controlled through sinusoidal PWM (SPWM), and the harmonics are directly associated with the switching frequency of each converter leg. Each phase leg of the converter is connected through a reactor to the ac system. Filters are also included on the ac side to further reduce the harmonic content flowing into the ac system .the relative location of the phasors of the two ac sinusoidal quantities and their relationship through the voltage drop across the line reactor. One voltage is generated by the VSC and the other one is the voltage of theac system. At the fundamental frequency, the active and reactive powers are defined by the following relationships, assuming the reactor between the converter and the ac system is ideal (i.e.,lossless):

- Avoidance of commutation failures due to disturbances inthe ac network.
- Independent control of the reactive and active power consumed or generated by the converter.
- Possibility to connect 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.

- Faster dynamic response due to higher PWM than the fundamental switching frequency (phase-controlled) operation, which further results in reduced need for filtering,and hence smaller filter size.No need of transformers to assist the commutation processof the converter's fully controlled semiconductors.

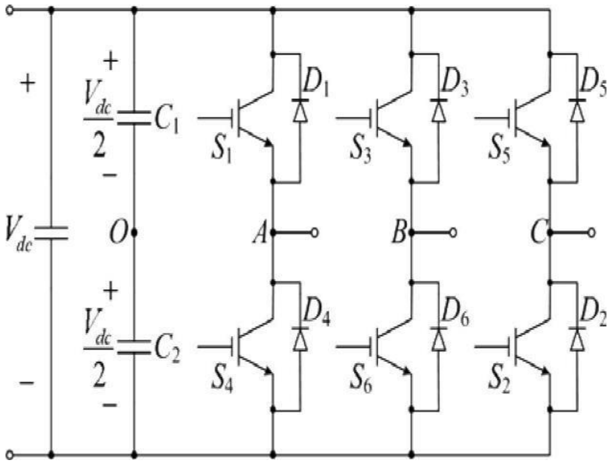


Fig No 1 Conventional three-phase two level VSC topology

3.1 VSC-HVDC Multilevel Topologies

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

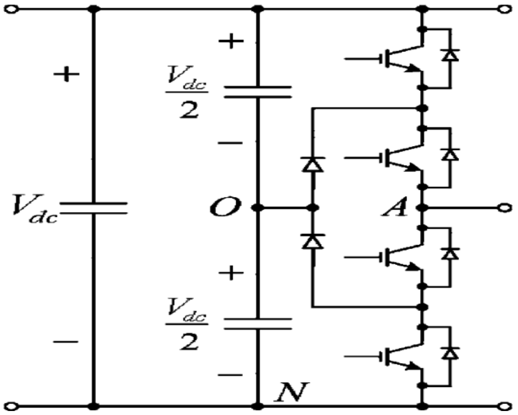
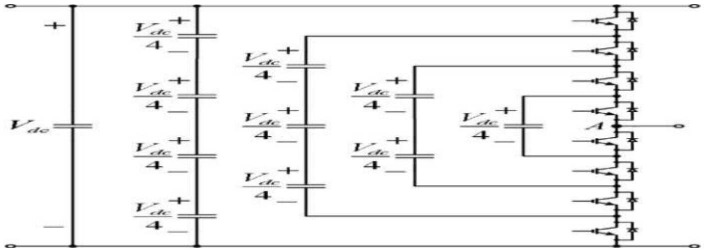


Fig. No 2. NPC phase leg.

There are numerous multilevel solid-state converter topologies reported in the technical literature. However, there are two distinct topologies, namely, the diode-clamped neutral point-clamped (NPC) converter (see Fig.1) and the flying capacitor (FC) converter (see Fig. 2). For clarity purposes, three-level and five-level PWM voltage waveforms on theline-to-neutral basis are shown in Figs. 3 and 4 ,respectively. Contributions for selected topologies that can be used to build an HVdc system were made in numerous technical papers. Specifically, PWM controlled HV dc concepts based on the three-phase two-level converter were reported using GTOs. A similar system was developed and reported using IGBTs and DSP control. Using modular approach and phase-shifted SPWM concepts, a number of advantages can be gained as far as the harmonic performance of the overall VSC-HV dc system is concerned. The diode-clamped NPC topology was studied in for an HV dc system in its three-level version(see Fig. 1). The benefits of using such a system were brought out; however, the converter has significant challenges with voltage balancing across the various dc bus capacitors, in addition to the uneven loss distribution between the devices. An actively clamped topology that is able to offer a solution to the loss distribution problem of the NPC was introduced in and is called active NPC (ANPC) converter. This topology is anattractive solution for HVdc applications.



FigNo 3. Five-level FC VSC phase leg.

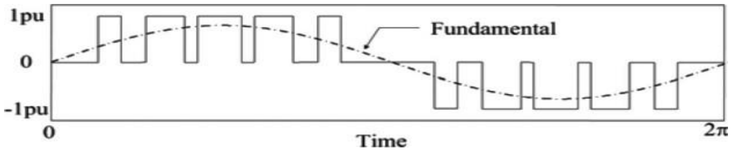


Fig.No 4 .Three-level PWM line-to-neutral voltagewaveform.

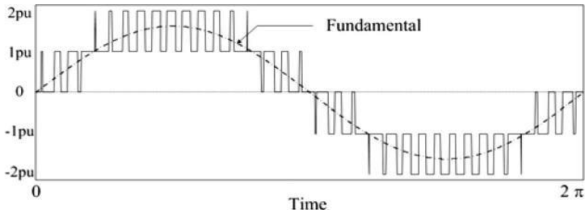


Fig.No 5.Five-level PWM line-to-neutral voltagewaveform.

IV. CONTROL MODES FOR DIFFERENT CONVERTERS

In a typically configured MTDC system, there exist two kinds of converters: grid side converter (GSVSC) and wind farm side converter (WFVSC). GSVSC and WFVSC have different working modes, determined by the DC voltage and current.

A four terminal MTDC network is studied, as shown in Figure 6 On the left side of MTDC is the WFVSC integrating various wind farms, such as DIFG or full converter based induction generators. The duty for the WFVSC is to deliver all the possible wind power collected by the wind farm to the DC cable, meanwhile maintaining the AC side voltage or providing reactive power support if necessary. The GSVSC will try to control the DC voltage at a desired level, delivering the power out of the DC cable. Proper power transfer is indicated by the DC voltage. If the injected power is higher than delivered, the DC voltage will rise, otherwise it will fall. Thus for a MTDC network in normal operation, the basic tasks are to transfer power while maintaining the DC voltage.

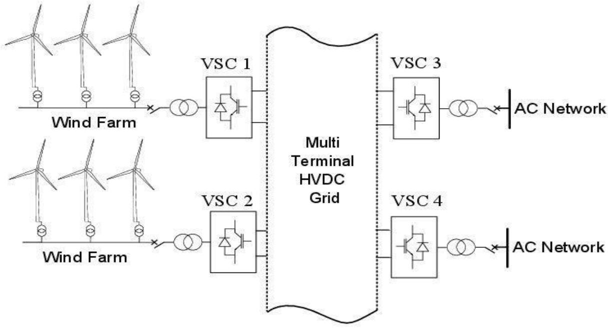


Fig No 6Typical four-terminal HVDC network

V. SYSTEM DESIGN

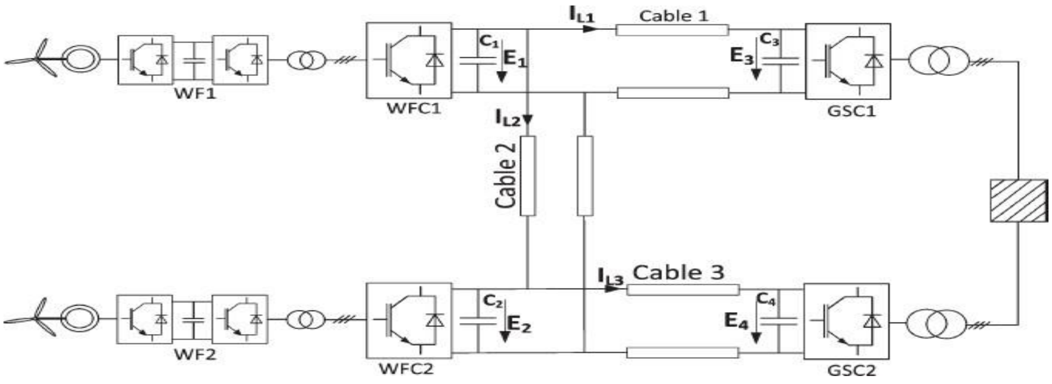


Fig No 7 Scheme of the simulated M-HVDC system.

5.1 Control Design

The control scheme consists of two control levels. The first level is the current control of each converter, which is achieved by using conventional flux-oriented control method . The second level is the dc voltage regulation which is achieved by using decentralized control strategy designed to allow proper transmission of the generated power from the WFCs to the GSCs while maintaining the voltage of the HVDC in a safe range of operation.

1) Current Control

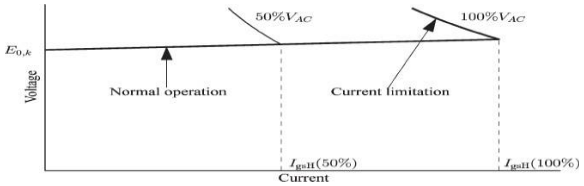


Fig No 8 Static current–voltage characteristic of a GSC. The thin line shows the characteristic under a voltage sagof 50%

5.1.2. Voltage Control

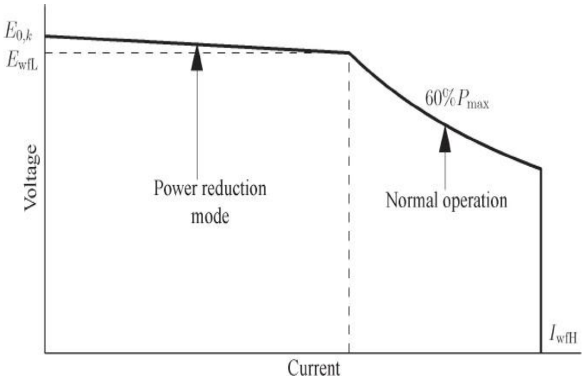


Fig.No 9 Static current–voltage characteristic of a WFC

The purpose of the voltage control is to ensure an adequate power transmission and it should be decentralized so that the control law applied by an HVDC converter only depends on local measurements made by that converter and does not need to rely on long distance communications between different terminals. The common formulation of this controller is the so-called droop control concept. The droop controller is a proportional control law that regulates the dc voltage and provides power sharing between the different power converters. During normal operation mode.

VI. SIMULATION

The system under analysis is a M-HVDC transmission system with four terminals: two offshore wind farms and two onshore main ac grid connections. The two offshore wind farm VSC (WFC) power converters inject the power generated in each wind farm into the HVDC grid, whereas the grid-side VSC (GSC) power converters inject the power from the HVDC grid into the main ac grid. The HVDC grid consists of three submarine cables: Two of them connect each wind farm to an onshore VSC, while a third tie cable connects the two wind farms together in order to provide redundancy and share the power injected by each onshore converter.

The simulated system is an offshore M-HVDC transmission system fed by two wind farms equipped with FPC wind turbines. The simulated system is shown in Fig. 6.1. Three different scenarios have been considered: when load is reduced in the wind farms, when load is increased in the wind farms, and when wind farm1 is disconnected. For both control schemes, the current controllers have been tuned to achieve a time constant of 10 ms.The droop designed following the steady-state methodology has been designed to reach the nominal voltage under steady-state conditions when the system is transmitting the nominal power.

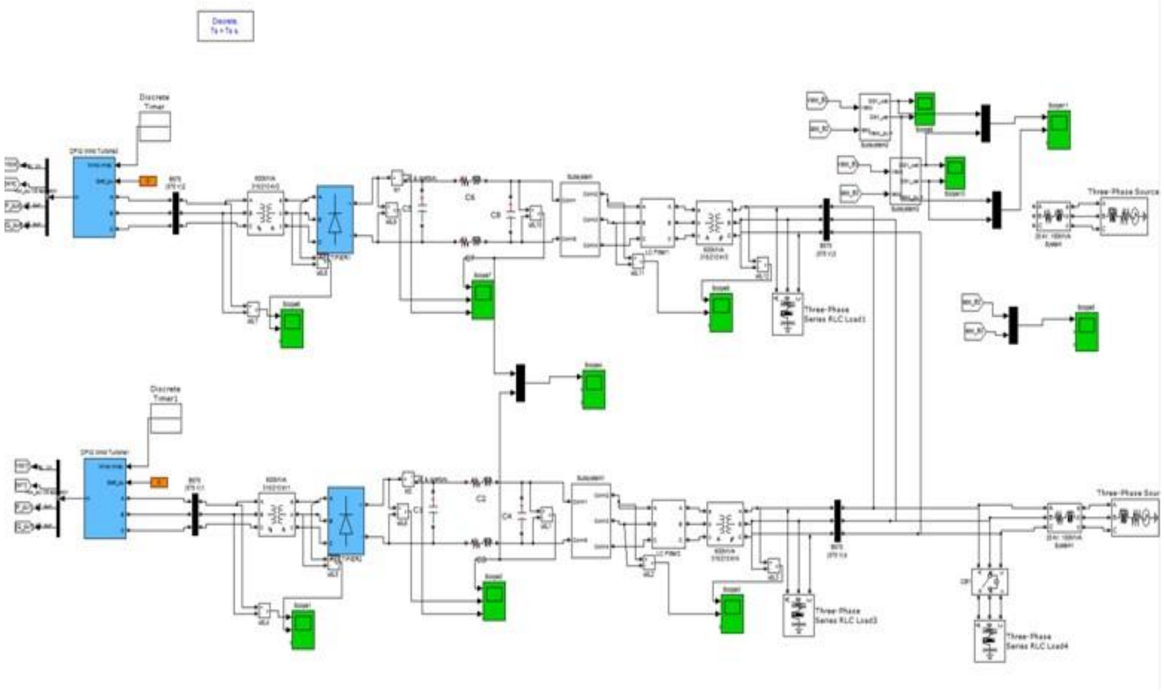


Fig No 10 Scheme Of The Simulated M-HVDC System.

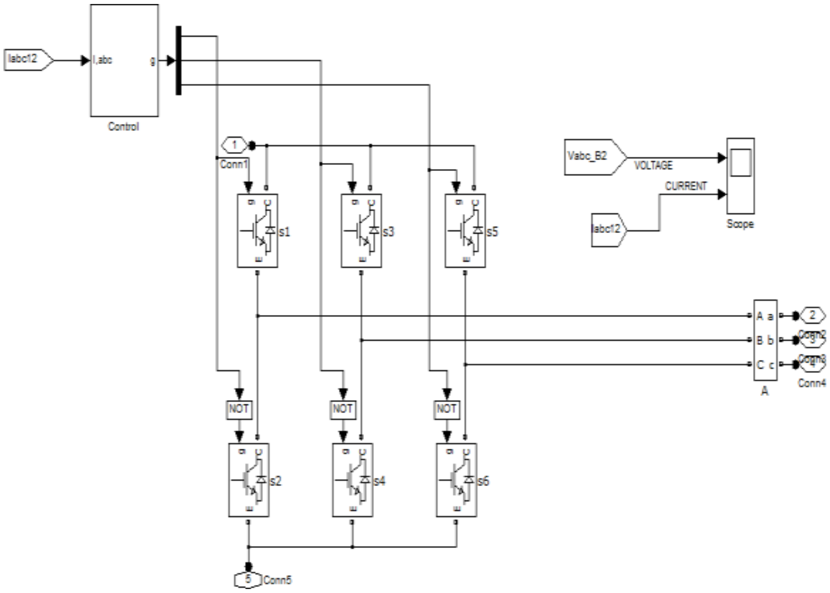


Fig No 11 Subsystem Model

The purpose of the voltage control is to ensure an adequate power transmission and it should be decentralized so that the control law applied by an HVDC converter only depends on local measurements made by that converter and does not need to rely on long distance communications between different terminals. The common formulation of this controller is the so-called droop control concept . The droop controller is a proportional control law that regulates the dc voltage and provides power sharing between the different power converters. During normal operation mode, the WFCs inject all the generated current into the HVDC grid, while the GSCs maintain the dc voltage almost constant.

VI. CONCLUSION

This Paper has addressed the operation and control of multiterminal VSC-HVDC transmission farms. A droop-based control scheme has been designed to ensure the dc grid voltage stability, wind farm power correct evacuation, andpower sharing between the grid-side converters. The M- HVDC lattice has been mimicked considering a megawatt-range power framework in three different contextual investigations: when burden is diminished in the breeze ranches, when burden is expanded in the breeze homesteads, and when wind farm1 is detached. Recreations shows a the proposed hang plan procedure. The impact of matrix side DC voltage change on the transmission misfortune has been investigated. It is found that in order to achieve the minimal transmission loss the grid side DC voltage should be equal with an ideal constant current input from the wind farm side. However, when the wind farm side VSC works in constant power mode, this requirement will change due to the power characteristic of the wind farm power injection. Simulations have been carried out in Simulink and the analysis is verified by simulation results.

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