MODELLING AND IMPLEMENTATION OF MULTILEVEL CONVERTER FOR HVDC CONNECTED OFFSHORE WIND ENERGY SYSTEMS

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Abstract -This paper presents several multilevel modular DC/DC conversion systems based on the capacitor-clamped module concept for high power offshore wind energy applications. Two types of the capacitor-clamped modules, the double-switch module and switchless module, are discussed. A soft-switching technique is adopted to achieve minimal switching losses and the maximum system efficiency. Theoretical analysis is carried out for the 2n+1 level cascaded configurations based on the capacitor-clamped modules. The inherent interleaving property of the proposed configurations effectively reduces the output voltage ripple without adding extra components. A cascaded hybrid topology is developed by the combination of double-switch and switchless modules. The proposed hybrid topology achieves higher efficiency and lower component count.

***Key Words*: Capacitor-clamped module, cascaded configuration, double-switch module, offshore wind energy, soft-switching technique, switchless module.**

1. INTRODUCTION:

Wind energy is an important renewable and green source of energy. A recent trend is to install large offshore wind power plants (WPP) because they offer higher energy yield due to a superior wind profile as compared with land based installations, and provide a reduced level of irritation to the general public as noise, tower shadow and visual impact are not a significant problem. Offshore wind power must be connected to the onshore power grid for the subsequent distribution and consumption of the generated power. For distant offshore wind power plants, high voltage dc (HVDC) transmission becomes favourable compared to high voltage ac (HVAC) transmission. In the MMC, several elementary switching sub-modules are stacked together to attain the required dc operating voltage. Unlike other high voltage VSC topologies, the MMC avoids the difficulty of connecting semiconductor switches in series. The voltage rating can be scaled by simply adding additional sub-modules to the stack. Thus, it becomes easier to construct VSCs with very high power and voltage ratings. The MMC arrangement also has significantly lower switching losses. A soft switching technique is used to reduce switching losses and provide a high efficiency for MMCC topologies. The capacitor clamped multilevel converter is used for high power offshore wind energy applications. There are two types of the capacitor-clamped modules, the double-switch module and switchless module, are discussed. The cascaded SL- and DS-based topologies are used to achieve the high voltage gains at high efficiency in offshore wind applications. The Multiple-module boost converters were represented to achieve a high voltage conversion ratio for offshore wind energy applications connected to an HVDC line. In the existing system, a large duty ratio of the main switch is used to achieve high voltage gain. Because of it, the switching frequency is limited to reduce losses and obtain sufficient turn-off time for switches. Therefore, increasing the size of the passive components, such as boost inductors and filter capacitors, is inevitable due to the low switching frequency. This project has proposed the modular multilevel converter based on capacitor clamped multilevel converter for offshore wind energy systems to interface with high voltage transmission networks. This project extends the CC module concept and proposes two different CC module structures, the double-switch (DS) module and active switchless (SL) module. Each module provides a high degree of modularity by the combination of two top and bottom cells. A resonant technique is adopted to achieve a soft-switching scheme for all switches. A combination of SL- and DS-based modules is possible and total power handling is distributed among the components differently to reduce component count and cost for a cascaded hybrid topology. Then, 2n+1 level cascaded DS- and SL-based configuration with their properties are demonstrated to achieve a high voltage gain for offshore wind energy systems. Based on these properties, the cascaded SL-DS- and SIL-DS-based configurations are proposed to reduce component count and cost in the system.

2. PROPOSED SYSTEM:

2.1 Module Structure:

The SL-based module presented where a five-port system consists of two top and bottom cells. Each cell includes two capacitors, one inductor, and two diodes.

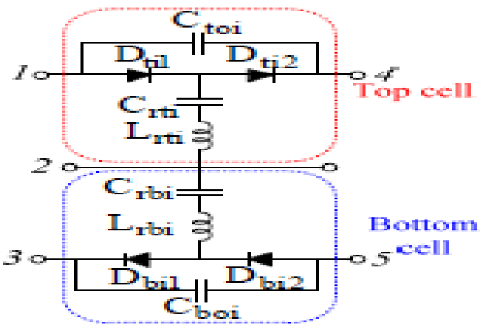


Fig-1.SL Based Module.

The DS-based module is depicted which is a six-port system with two cells in the top and bottom of the module. Each cell of the DS-based module is composed of a single active switch, one diode, one inductor, and one capacitor

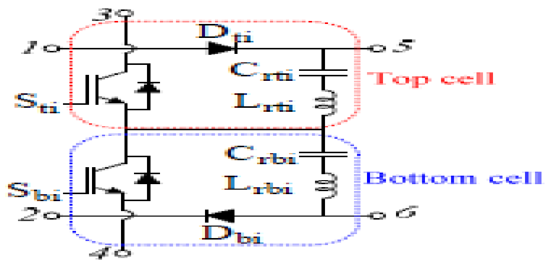


Fig-2.DS-Based Module

In the cascaded SL-based circuit, an input module is connected to module #.

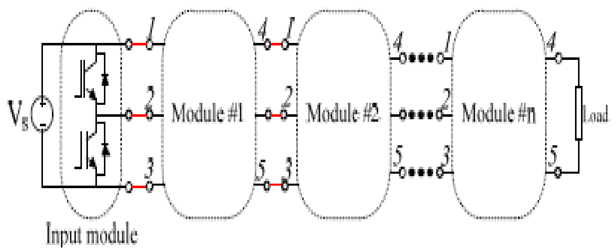


Fig-3.SL-Based Input Module

In the cascaded DS-based topology, ports 5 and 6 of module #n are connected to an output module that consists of two capacitors and two diodes.

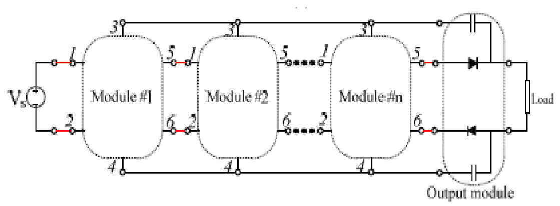


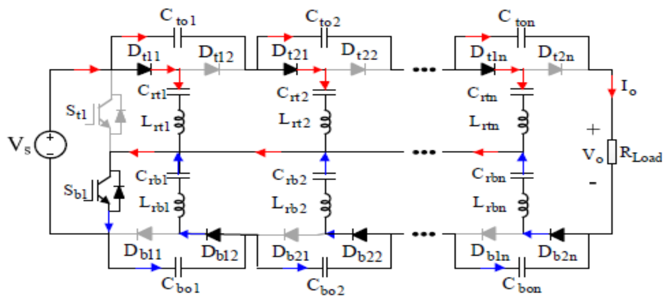
Fig-4.Ds Based Output Module

2.2. OPERATING PRINCIPLES:

2N+1 LEVEL CASCADED SL-BASED CONFIGURATIONS:

The 2n+1 level cascaded SL- and DS-based topologies implemented with the same principle of a single stage structure. Note that n is an even number.

MODE I



During the period of t0 to t1, the bottom switch Sb is ON, whereas St is OFF. In each top cell, the diodes Dti1s (i=1, 2... n) are forward-biased by Vs and Ctois. Therefore, Crtis are charged by Vs and Ctois (i=1, 2... n-1). In this mode, Cton is discharged to the load. In contrast, in the bottom cells, Crbis are discharged to the output capacitors, Cbois.

For the general 2n+1 level cascaded SL-based topology, the currents through the top and bottom capacitors are,

$$i_{C_{rti}}(t) = \frac{\pi P_o}{V_o}\sin(\omega_r t) \quad (i = 1, 2, \ldots, n), \qquad (1)$$

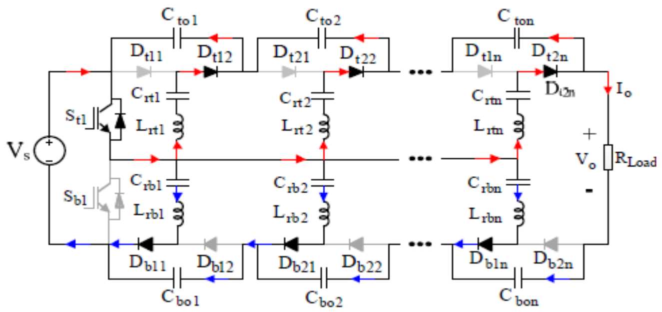
$$i_{C_{rbi}}(t) = -\frac{\pi P_0}{V_0}\sin(\omega_r t) \quad (i = 1, 2, \ldots, n). \qquad (2)$$

Voltages of the top and bottom resonant capacitors can be obtained as follows:

$$v_{C_{rti}}(t) = iV_s - \frac{\pi P_0}{V_0 C_{rt1}\omega_r}\cos(\omega_r t) \quad (i = 1, 2, \ldots, n), \qquad (3)$$

$$v_{C_{rbi}}(t) = iV_s + \frac{\pi P_0}{V_0 C_{rt1}\omega_r}\cos(\omega_r t) \quad (i = 1, 2, \ldots, n). \qquad (4)$$

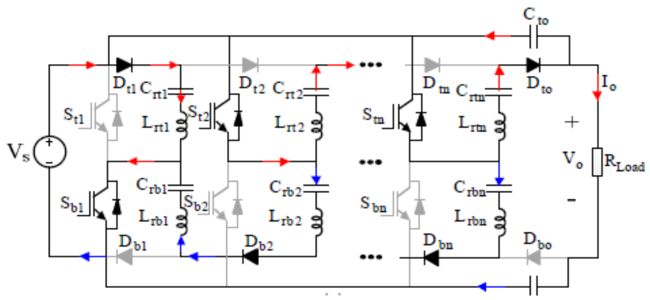
Mode III:



When the top switch St is in the ON-state and Sb is in the OFF-state at t0. The top diodes Dti2s and bottom diodes Dbi1s are forward-biased. In the bottom cells, Crbis are charged by Vs and Cbois (i=1, 2, ..., n-1), whereas Crtis are discharged to Ctois. As a result, the voltages of Crbis are equal to i times the input voltage level.

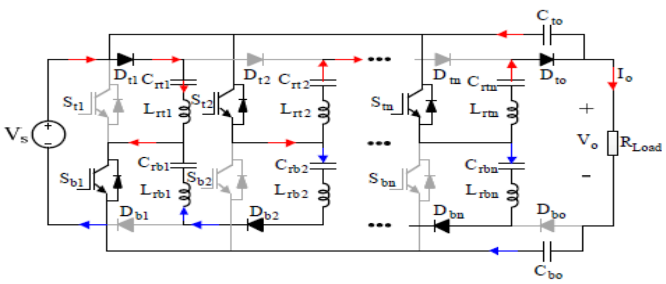
2n+1 LEVEL CASCADED DS-BASED TOPOLOGY:

MODE I:



At t = t0, Sbi (i=1, 3, ..., n-1) and Sti (i=2, 4, ..., n) are turned ON, whereas Sbi (i=even) and Sti (i=odd) are OFF in the top and bottom cells. Therefore, in the top and bottom cells, the odd numbered Crtis and even numbered Crbis are charged by Vs, Crtis (i=2, 4, ..., n), and Crbis (i=1, 3, ..., n-1). In this state, the output capacitor Cto is charged by Crtn, whereas Cbo is discharged to the load.

MODE II:



During this time interval, Sbis (i=1, 3, ..., n-1) and Stis (i=2, 4, ..., n) are OFF, whereas Sbis (for i even) and Stis (for i odd) are ON. Therefore, in the top cells, Crtis (i=1, 3, ..., n-1) are discharged to Crtis (i=2, 4, ..., n). On the other hand, the odd numbered Crbis are charged by Vs and the even numbered Crbis.

3. SIMULATION RESULTS AND COMPARISONS

Offshore wind farms in the MW range are required to interface with high voltage power transmission systems .However, the output DC voltage level has a large impact on efficiency and power density of MV and HV DC/DC converters , Also, it depends on the power rating of wind farms, DC layout, and its distances to the shore. For example, the HVDC transmission of the BorWin 1 offshore wind farms (400 MW) is 300 kV [26] whereas the HVDC level of offshore wind farms (300 MW) is set to 150 kV .

The overall simulation model of the proposed topology and is simulated using simulink matlab software using the PLECS Blockset and evaluated for high voltage gain and high rated power. Five and Seven stage MRCC outputs are taking place. That is here we are giving an input of 10V and in simulation we are getting the output of 150V. It is equal to three times of the each stage output. So we can justify that the simulated prototype model is having voltage tripler related with the input voltage.

If the proposed module-based converter boosts the DC-link voltage to an MV level for lower voltage wind turbines, an offshore station with a step-up DC/DC stage is required to meet an HVDC level. The remaining voltage gain of 15 is provided by a 7 stage cascaded SL-DS-based converter. The cascaded MRCC converter by itself has a poor regulation property; it only realizes a designed high voltage gain and high efficiency with a fixed 50% duty cycle. The simulation results closely match the analysis and operation of the cascaded topology.

The output capacitor voltages have a 180º phase shift with respect to each other. Therefore, the output voltage has a frequency two times the switching frequency. In this analysis, the reverse-recovery loss of diodes and turn-on loss of active switches are neglected. Power device conduction losses can be calculated using a device approximation with a series connection of a dc-voltage source and a collector-emitter on-state resistance. It can be observed that the SL-based converter requires a larger switch count compared to the DS- and SL-DS-based topologies because the SL-based module topology draws a high current rating for both switches, which results in an increased number of switches in the parallel connection. The SL-based converter has higher capacitor loss due to the larger number of capacitors with the high current ratings.

Here, the proposed multiple-module configuration is evaluated against other high voltage DC/DC converters represented for HVDC-connected offshore wind energy systems. The cascaded DC/DC Marx and cascade-boost converters require two stages so that the stages 1 and 2 provide the voltage gains of 3 and 5, respectively. A lower switching frequency is considered for the cascade-boost topology because of the hard-switching technique. The cascaded DS-based topology can achieve equal power sharing among its modules. Therefore, a lower voltage/current stress is experienced by the switching devices than that of the other approaches. A lower voltage/current stress means lower losses, smaller device count, fewer failure points, and lower cost

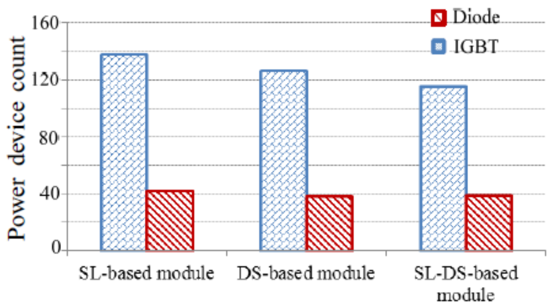


Chart-1.Power device count comparison

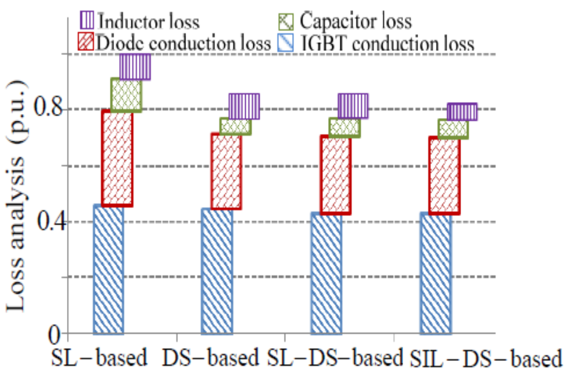


Chart-2.Loss comparison

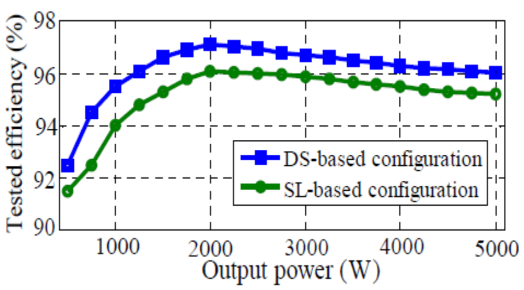


Chart-3.Efficiency curve with different output power

4. Conclusion:

This project has presented a family of MMC dc-dc converters. The dc capacitors of the cells are used also for resonant operation. The equivalent operating frequency can be increased as a function of the number of chopper cells and the voltage step-up ratio is also dependent on the number of the cells for offshore wind energy systems to interface with high voltage transmission networks. The proposed converter has a simple configuration and inherent-balancing capability. In this project, two CC modules are introduced: the SL- and DS-based modules. A voltage Tripler converter based on these modules minimizes the switching losses significantly. The inherent interleaving property of the proposed modules effectively reduces

Output voltage ripple without adding extra components. The cascaded SL- and DS-based topologies are introduced to achieve the high voltage gains at high efficiency in offshore wind applications.

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