Start-Up Control of an Offshore Wind farm

Mr. Mukul G. Yadav
Lecturer, G. H. Raisoni Polytechnic, Nagpur. (India)

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Abstract: The modular multilevel converter (MMC) provides promising development for high-voltage direct current (HVDC) applications, including multi-terminal HVDC (MTDC) and renewable energy integration. This paper, considering an offshore wind farm (OWF) integrated MMC MTDC system, investigates its start-up process with three main developments: 1) it further develops the mathematical model of MTDC with active networks and proposes a hierarchical start-up control scheme; 2) for the terminal which connects the OWF, it proposes a reduced dc voltage control scheme of mitigating the current surges with deblocking the converter at zero voltage difference on sub-modules (SMs) and proposes an overall sequential start-up control scheme for the offshore integrated MTDC. The simulation results verify effectiveness of the proposed scheme on the MMC MTDC system with two control paradigms, i.e., master–slave control and droop control, respectively. In comparison with different start-up control schemes, the superiority of the mitigation of voltage spikes and current surges are shown using the proposed scheme with less complexity and easier implementation.

Keywords— Droop control, master–slave control, modular multilevel converter (MMC), multiterminal HVDC (MTDC), offshore wind farm (OWF), sequential start-up control.

I. INTRODUCTION

With extensive research and applications, VSC technology has gradually achieved a high degree of maturity, and there have been numerous projects on VSC-based HVDC applications, including the applications of MTDC and renewable energy integration in recent years. There has been a variety of topologies with the VSC development. Among them, one of these, the MMC, has salient features and shows its strong competitiveness, which has been well recognized by research and applications. Since there are a number of energy capacitors in the SMs of the MMCs, it is important to pre-charge these capacitors during the start-up stage and the system start-up control is essential.

In a start-up control scheme for the MMC was proposed. The proposed control scheme was based on the control of an auxiliary voltage source at the MMC dc-side. However, it is generally expected to start a system without auxiliary sources, which saves space and costs. In, a start-up technique using additional resistor was proposed. The resistors were connected on the converter arms and were inserted/bypassed to limit the arm current. However, the additional resistive losses were not expected. In, a start-up scheme with a two-stage charging process for MMC was proposed. Although the proposed charging scheme seemed to achieve charging the voltage of each SM capacitor to the rated value without auxiliary dc source, it had two main problems. First, in the first charging stage, the dc voltage was assumed to be the rated value and the charging of the SM capacitors was from the dc side. Under this assumption, the proposed scheme was only valid for the MMC under inverter operations. Second, in the second charging stage, the proposed scheme was that the SM capacitor voltages were charged to the rated value when the SMs were deblocked. However, the main objective of the start-up control of MMC is to pre-charge the SM capacitors to the rated value before they are deblocked. A start-up scheme for MMC HVDC was proposed in, including the calculation of the limiting resistance, the setting of the rising slope of dc voltage and the reference setting of reactive power.

One way to do so is by slave-master configuration where there is one master-terminal dedicated for the dc bus voltage regulation and others are set for constant power control mode. In this control scheme the functionality of the whole MTDC link always depends on the presence of the master-terminal in the grid leading to breakdown of the whole system during failure of the master terminal.

An alternative solution to avoid this problem is the use of dc voltage regulation by voltage droop control at several terminals. In this paper a modified version of the dc voltage droop control is proposed and simulated. The modification imposes movable upper and lower power limits on the droop characteristic curve so that the control mode of a terminal can be easily changed between constant P and constant DC voltage operations.

II. PROBLEM DEFINATION

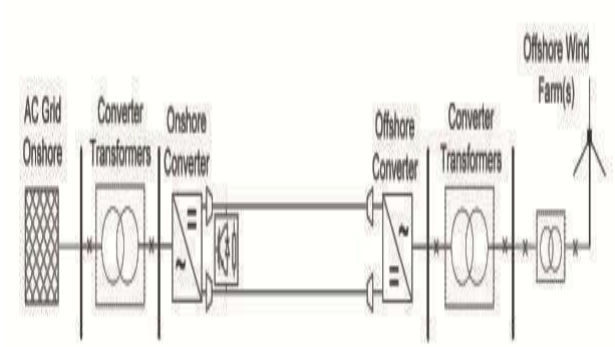

Fig.1: System with single OWF and single terminal onshore connection.

The example system model in Fig. 1 comprises a system with single OWF and single terminal onshore connection to ac grid. The performance of above system is observed with and without start-up schemes. It has been observed that with start-up schemes applied the working of the system was better as compared to the system without start-up sequence.

In the proposed work it has been planned in improving the control strategies during the start-up period of offshore integrated wind farms.

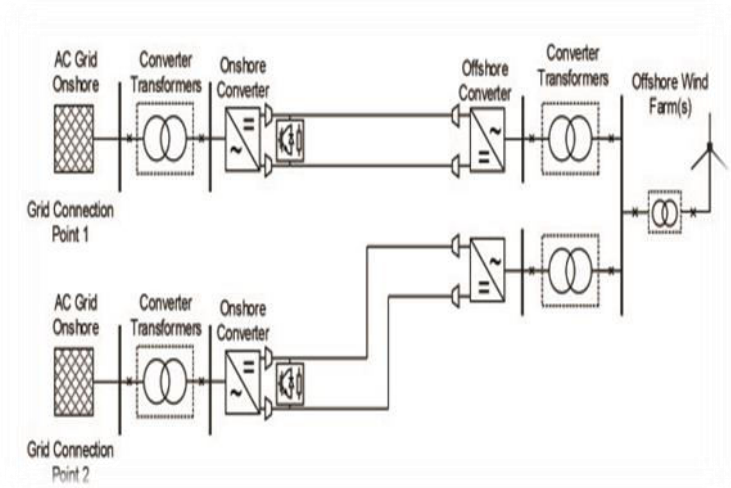

Fig.2: System with single OWF and multi-terminal onshore connections.

III. OBJECTIVES

Start-up control technology is becoming more and more popular due to due to improvement in Power Electronics technology and reduction in costs. If the system is started without considering any starting sequence, such as starting the terminal with active power control prior to the dc voltage controlled terminal or connecting the OWF when the ac voltage at the wind farm side has not been well stabilized, the performance may become much worse with significant overvoltage and over current and there may be difficulty in integrating the OWF. The control methodology is easy to realize without complex strategies.

The project work is targeted towards improving the control strategies during the start-up period of offshore integrated wind farms. To study the offshore wind farms & its control strategy in detail. Comparative analysis of start-up control strategies with that without start-up control in case of offshore wind farms.

IV. DESCRIPTION OF PROPOSED WORK

Our proposed technique involves implementing the control scheme based on the control of an auxiliary voltage source at the MMC DC-side. It is generally expected to start a system without any auxiliary source to save space and cost.

A. Methodologies

a. Develop a system based on the start-up control technique for offshore wind farms.
b. To develop the mathematical model of MTDC with active networks and proposes a hierarchical start-up control scheme.
c. To propose a reduced dc voltage control scheme of mitigating the current surges with deblocking the converter at zero voltage difference on sub modules (SMs) and proposes an overall sequential start-up control scheme for the offshore integrated MTDC
d. To analyse and compare different start-up control schemes.
e. To evaluate the proposed sequential start-up control scheme, an offshore MMC HVDC system is established on the RTDS.

conclusion

The start-up control of an OWF integrated MMC MTDC system has been investigated. After the derivation and analysis of the mathematical models on both the active and passive networks connected MMCs, a hierarchical control scheme for the active network connected MMCs and a reduced dc voltage control scheme for the OWF connected MMC have been proposed. The combination of both schemes forms an overall sequential start-up control scheme. A four-terminal MMC HVDC system with one terminal connected with an OWF has been established on the RTDS.

The system with either master-slave control or droop control can be well started using the proposed control scheme with small voltage spikes and current surges. In comparison

with the start-up control schemes with/without starting resistor and half dc voltage control, the superiority of the proposed scheme has been observed. This paper has also discussed the potential development on the proposed scheme and the importance of the sequential start-up for the MTDC. The proposed sequential start-up control scheme has less complexity and is easy to realize. Although half dc voltage control scheme may not be applicable for every MMC MTDC projects, the reduced dc voltage control scheme can be applied for all of them.

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