Grid Integration of offshore wind farms using a Hybrid HVDC composed by an MMC with an LCC-based HVDC system

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Objective

This paper presents a hybrid HVDC-transmission system composed by a Full-Bridge Modular Multilevel Converter (FB-MMC) and a Line-commutated Converter (LCC) to integrate offshore wind farms into the main grid. The operational characteristics of a three-terminal hybrid-HVDC system, two LCC stations and one MMC station, is investigated using PSCAD/EMTDC.

Introduction

In recent literature, the feasibility of grid integration of offshore wind farms using hybrid HVDC systems composed by voltage source converters (VSC) and line-commutated converters (LCC), have been investigated. Such a hybrid HVDC systems are attractive mainly because their low power losses compared to a VSC-based HVDC systems. However, hybrid HVDC systems have serious limitations when an ac fault occurs at the LCC inverter.

System description

The proposed configuration is shown in Fig. 1. It consists of two ac grids (AC1 and AC2) interconnected by a bipolar HVDC system with 12-pulse line-commutated converters. This HVDC transmission line is interconnected to an FB-MMC by means of a T-connection. This FB-MMC integrates offshore resources along the transmission line.

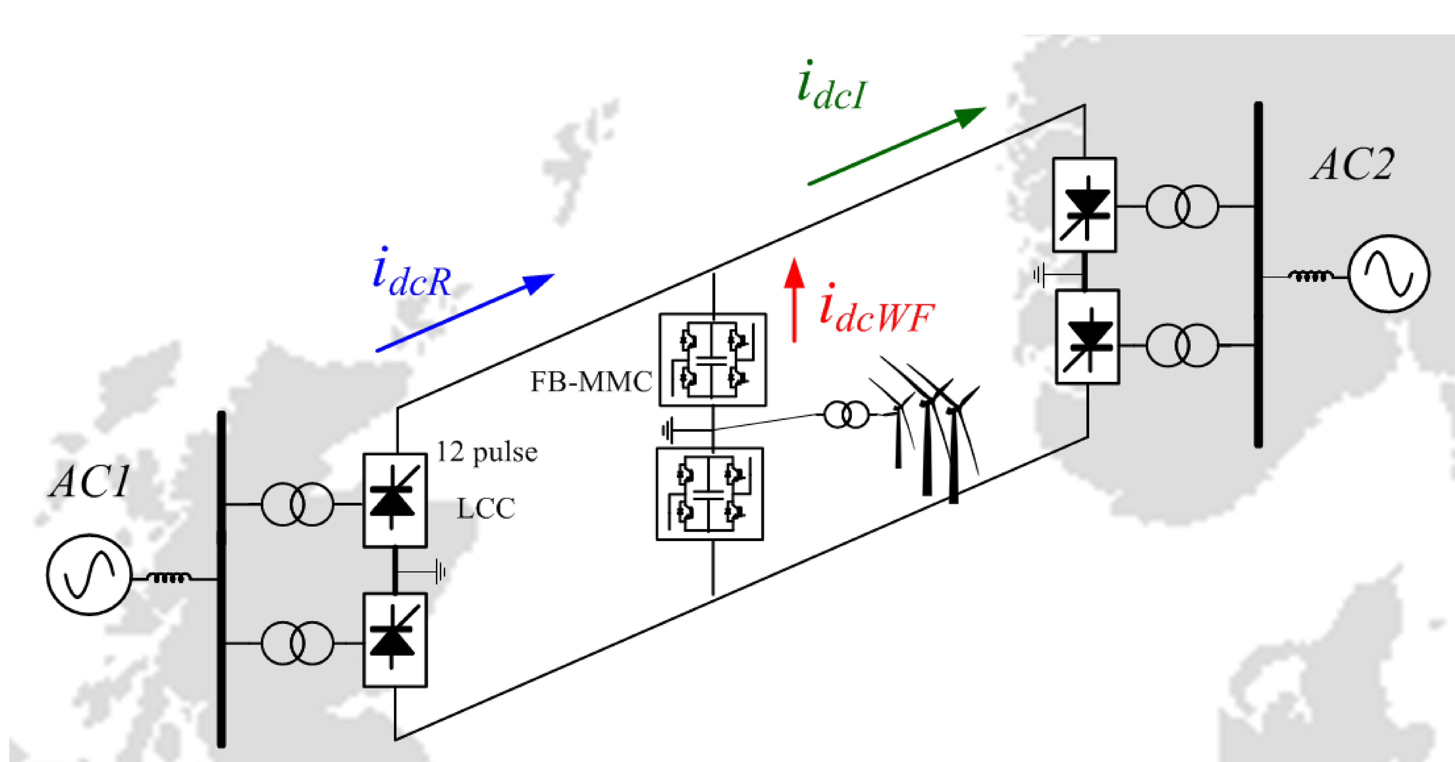


Figure: Proposed Hybrid HVDC for integration of OWF.

Proposed control design

The design of the controllers is divided into four sections: the LCC rectifier, the LCC inverter, the MMC, and the offshore wind farm.

- The LCC rectifier regulates the power extracted from one grid to another. In normal operation, the LCC rectifier operates in a constant DC current mode.
- The LCC inverter control objective is to regulate the DC link voltage.
- As power control is performed by the wind turbines, the main responsibility of the MMC is to establish the offshore ac voltage.
- Generally, a commutation failure (CF) occurs in LCC inverters when there is a significant voltage drop on the ac side. FB-MMC topologies can clear dc fault currents since they are build using full-bridge sub-modules which are able of suppressing the fault current against dc faults as shown as follows.

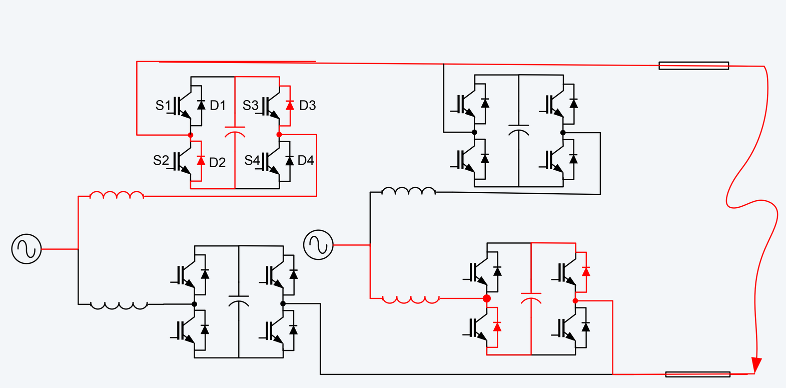
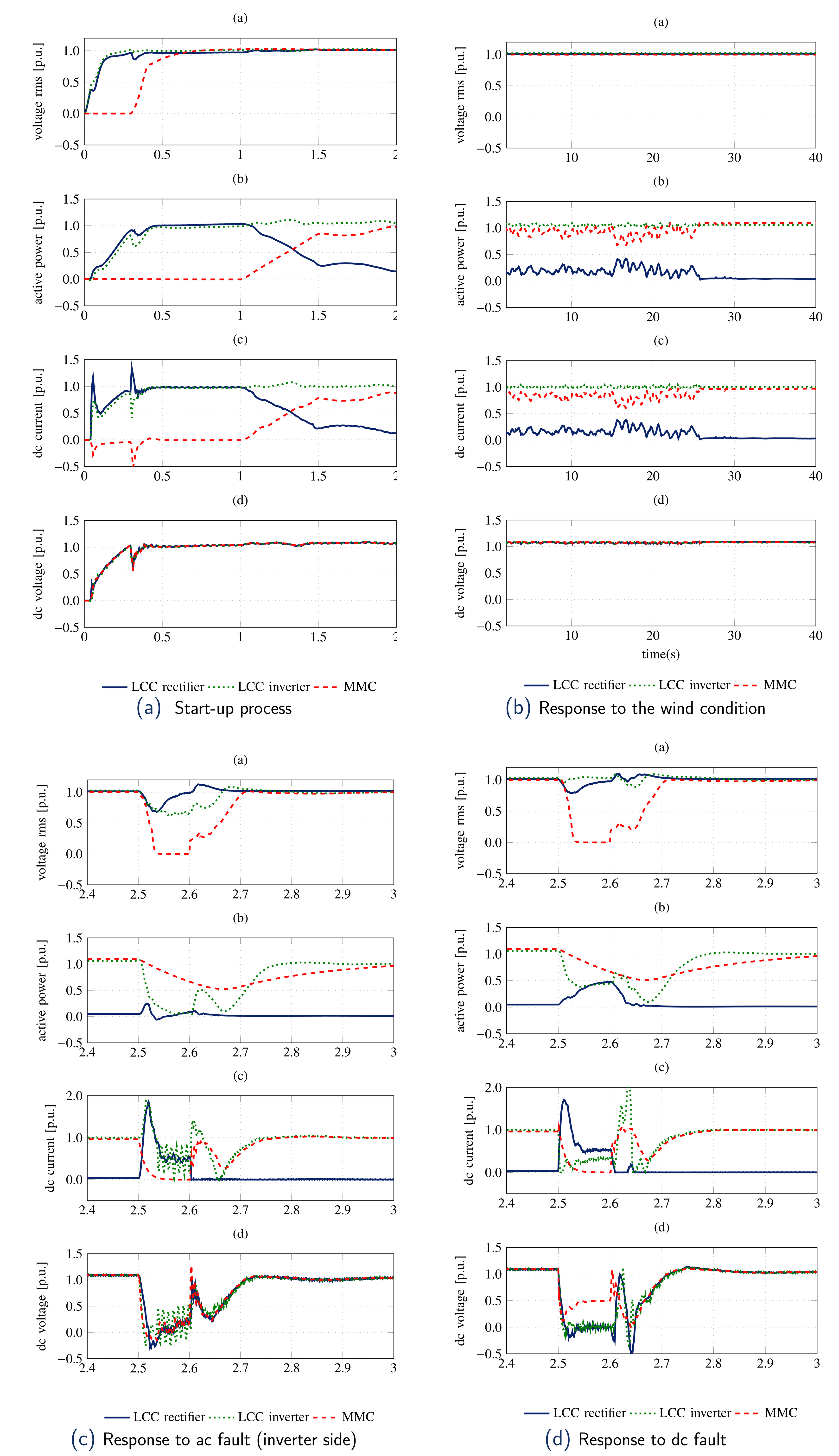


Figure: Full bridge MMC DC fault response

Simulation Results

The simulations were conducted under different conditions to investigate the operating characteristics of the proposed system. These conditions include start-up procedure, and ac and dc faults.



(a) Start-up process

(b) Response to the wind condition

(c) Response to ac fault (inverter side)

(d) Response to dc fault

Figure: [Top to bottom] (a) ac voltages (rms), (b) dc currents, (c) active powers, (d) dc voltages

Conclusions

AC fault is a very serious condition in a hybrid configuration because the commutation failure in line-commutated converters is translated into a dc fault in the voltage source converters. Full bridge MMC can provide a solution to this problem since they provide an available current path through the series connected capacitors of each MMC sub-modules.

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