DC Collection Network Simulation for Offshore Wind Farms

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Abstract

This work provides a study about the simulation of a medium voltage DC grid in an offshore wind farm [1]. The behavior in steady-state and during fault conditions is investigated. The efficiency of the network is determined in full-load conditions. Furthermore, key design aspects of such a grid are illustrated and issues regarding ripple current and converter design are treated.

Objectives

- Steady-state simulation of an offshore wind farm with a 30 kV MVDC grid connected with a HVDC model to an AC grid
- Highlight operational characteristics of a MVDC grid
- Show the voltage/current behavior during fault conditions
- Calculate the efficiency

OFFSHORE MVDC GRID OVERVIEW

Schematic of an offshore DC grid with parallel bus design, HVDC link, grid representation and control strategies responsible.

Methods

- Representation of components with electrical models
- Focus on DC/DC converter structure and control
- Implementation in EMTDC PSCAD, 4 Wind Turbines

Dual active bridge (DAB) DC/DC Converter design controlled by dual phase shift (DPS) [2] control mode. Modular structure of converter to decrease conduction losses, improved transformer efficiency and voltage sharing on medium voltage stage. High input and output ripple current needs to be taken into consideration [3].

Additional Components

<table>
<thead>
<tr>
<th>Generator</th>
<th>Type/Model</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC/DC Low Voltage Conv.</td>
<td>Synchronous Gen.</td>
<td>Torque Control</td>
</tr>
<tr>
<td>DC/HVDC High Voltage Conv.</td>
<td>Diode Bridge Rectifier</td>
<td>Passive</td>
</tr>
<tr>
<td>HVDC/AC High Voltage Conv.</td>
<td>Two-level-Full bridge IGBT D00 - PWM</td>
<td>Voltage regulator</td>
</tr>
<tr>
<td>MVDC Cable Model</td>
<td>Pl-Equivalent</td>
<td>None</td>
</tr>
<tr>
<td>MVDC Cable Model</td>
<td>Frequency Depended Phase Model</td>
<td>None</td>
</tr>
</tbody>
</table>

References


Results

Voltage stable but distorted current output in MVDC grid due to a lack of inductive components such as 50 Hz transformers!

Current flow - 30kV DC Grid - Current I1 and I4

Current ripple in two different positions in the grid without damping measures.

How to reduce the ripple current?

1. Adding Inductance

When the di/dt rises, the voltage at the output of the DC/AC converter changes, which can cause a voltage overshoot and reduce the stability of the converter. Adding inductance can help to reduce the current ripple and improve the stability of the converter.

2. Control strategy for DAB converter

Different control strategies can be used to reduce the current ripple. For example, a phase-shift control strategy can be used to reduce the current ripple by shifting the phase of the current.

3. Different Converter Design

Different converter designs can be used to reduce the current ripple. For example, a full-bridge converter can be used instead of a half-bridge converter to reduce the current ripple.

Conclusions

- DAB DC/DC Converter with high nominal input and output current ripple
- The MVDC grid needs to be stabilized with additional inductances and/or control strategies
- Due to low inductance, very fast DC breakers (tbr=1...1.5ms) [4] are essential to limit short circuit currents
- Grid efficiency is found to be 94.4% (Calculation includes conduction and switching loss of: diode rectifier, DAB converter, MVDC cables)