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On-Shore MML power converters for the connection of Diode Rectifier Units

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Abstract

The connection of large off-shore wind farms using diode rectifier units presents important advantages, due to the simplicity of the diode rectifier converter, its robustness and weight and loss reduction.

Moreover, series connected diode rectifier units allow for increased reliability as the system is capable of reduced power operation in the case of the failure of one unit. Diode rectifier converters require the use of full bridge on-shore MML power converters. Such converters allow for reduced HVDC-link voltage operation when one diode rectifier unit is faulty and also help to improve transient response during faults.

However, the full bridge MML is more complex than its half bridge counterpart and has higher losses. Therefore a study has been carried out to ascertain the advantages and disadvantages of using a mixed full-bridge half-bridge MML power converter for the diode rectifier connection of off-shore wind farms

Objectives

The main aim of this work is to study the use of hybrid half-bridge and full bridge on-shore MML power converters for the connection of large off-shore wind farms connected with diode rectifiers, regarding losses and operational capability when one Diode Rectifier station is faulted.

The minimum number of full-bridge cells required and the losses for different scenarios will be assessed.

Therefore, this study can be used as the starting point to evaluate the impact of different on-shore MML power converter topologies regarding risk, capital and operational costs.

Methods

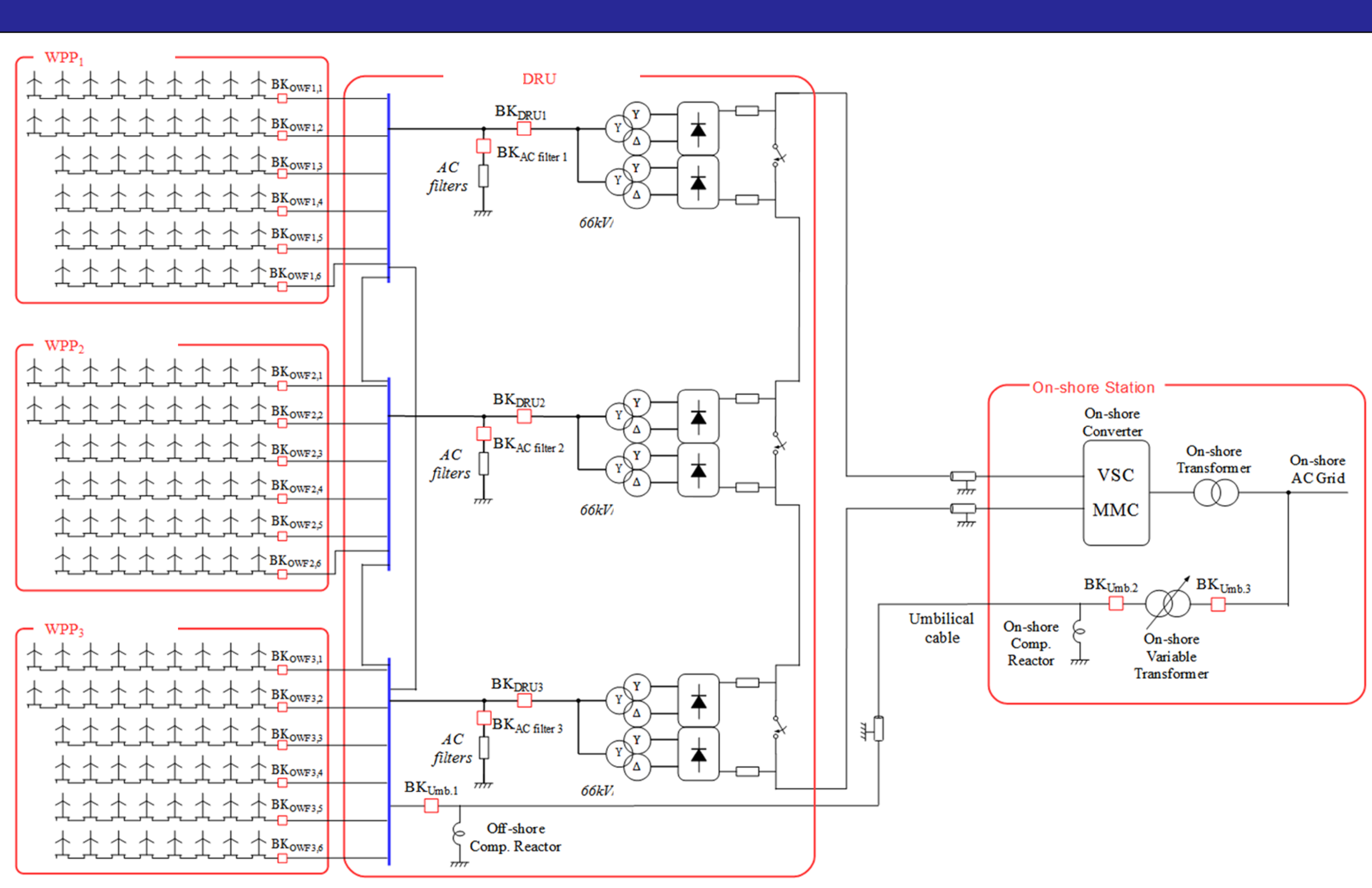


Figure 1. Diode Rectifier connected off-shore wind farms

The system under study is shown in Figure 1, where three off-shore wind farms are connected to the HVDC cable via three 12-pulse Diode Rectifier stations.

If one of the diode rectifier units is faulty, it will be by-passed by the corresponding dc-disconnector. Therefore the HVDC link will operate at a reduced voltage in one or both poles. This is one reason for requiring a full-bridge on-shore MML power converter.

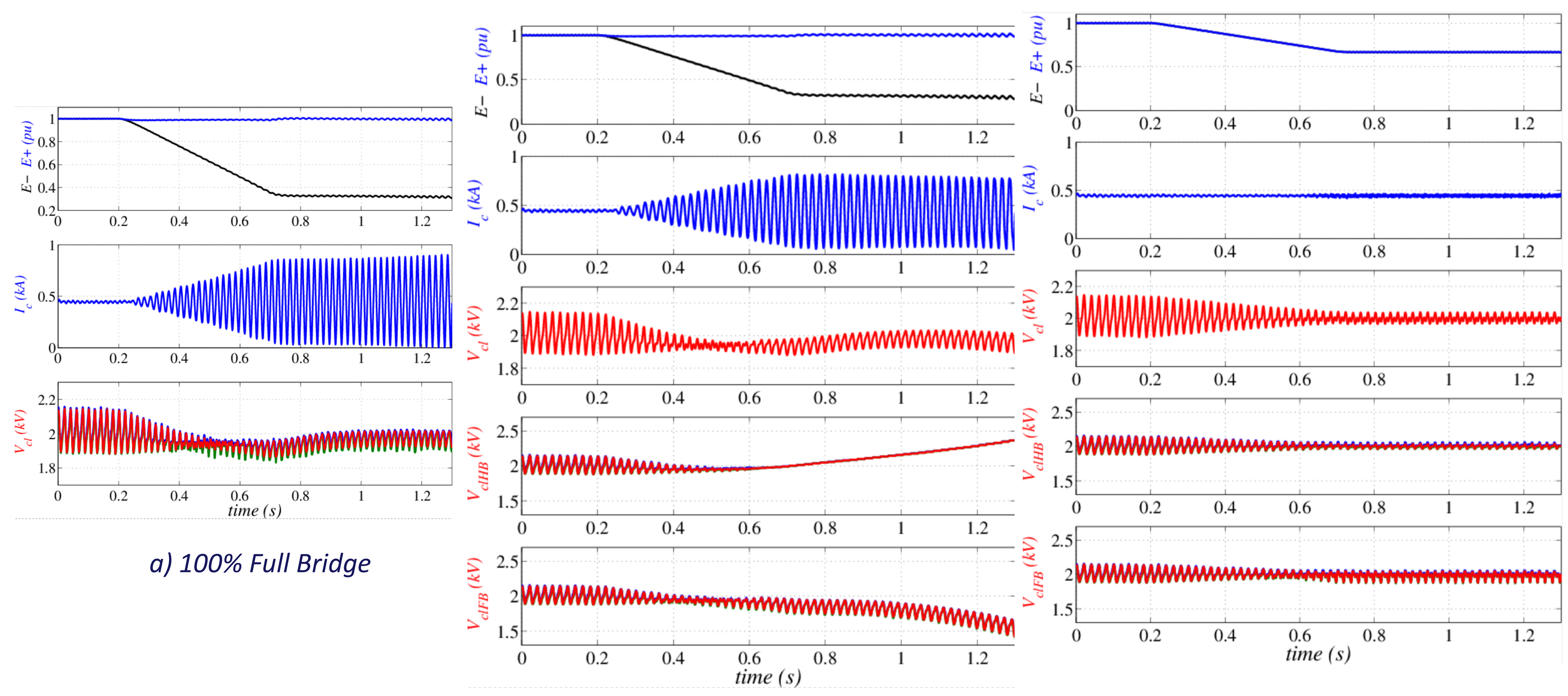
The minimum number of full-bridge cells for a single 12-pulse diode rectifier converter is calculated with and without pole-to-ground fault blocking capability.

This study covers both operation with symmetric and asymmetric pole voltage reduction in the event diode rectifier converter outage.

New control methods for the converter control and capacitor balance have been developed for mixed full and half-bridge cell MML power converter, considering both symmetric and asymmetric pole voltages.

Detailed EMT (PSCAD) simulations have been carried out to validate the controls and theoretical results.

Results



a) 100% Full Bridge

a) 35% Full Bridge asymmetrical

a) 17% Full Bridge symmetrical

Figure 2. Response with different converter configuration

Note the need of an additional circulating current to balance the energy stored in the top and bottom arms in case (a).

Case (b) shows that it is not possible to balance the top and bottom arms with asymmetric voltage, as the dc current + ac current for the bottom arms is always positive, therefore it is not possible to balance the capacitor voltage of the half bridge cells.

Case (c) shows the converter behaviour with 17% full bride cells, but considering a symmetrical reduction on pole voltage (either if the central diode rectifier converter is faulted or diode rectifier side ground terminal is switched to the correct location). No additional circulating current is required.

Conclusions

For operation with only one faulty 12-pulse diode rectifier converter (n-1 criteria), the on-shore MML power converter only requires 17% full bridge-cells, hence reducing normal operation converter conduction losses by more than 42% (i.e. almost half) with respect to the solution with 100% full bridges. In this case, the losses will be marginally larger than when using a half-bridge MML VSC station.

This solution requires that the voltage reduction is the same in both poles. Therefore, if either the top or the bottom Diode Rectifier stations are faulty, then the ground connection of the Diode Rectifier converters should be connected to the new resulting mid-voltage point.

The considered cost and loss reduction is achieved at the expense of losing the fault blocking capability offered by the full bridge MMC. However, pole-to-ground fault blocking capability can be achieved with only 50% full-bridge cells. Therefore, fault blocking capability can be kept while reducing MMC converter conduction losses by 25%. Moreover, operation with two faulty diode rectifier units will also be possible.

Therefore, important capital and operational expense reduction can be achieved by considering that only one Diode Rectifier converter can be faulty at any given time and using a mixed half and full-bridge on-shore MML power converter.

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