CONTROL OF HVDC DIODE RECTIFIER CONNECTED OFF-SHORE WIND FARM DURING CABLE FAULTS IN MULTITERMINAL HVDC GRID

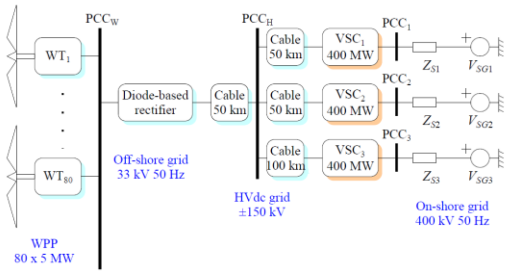
S. Añó-Villalba, S. Bernal-Pérez, R. Blasco-Gimenez
Universitat Politecnica de Valencia, Valencia, Spain
Presenting author: R. Blasco-Gimenez

Introduction

The presented work shows the application of a HVDC diode rectifier (DR) connected offshore wind farm (OWF), connected to a multiterminal HVDC grid. Previous work by the authors and others has shown that the OWF can adequately control the off-shore ac-grid frequency and current and also deliver optimum power to the HVDC grid[1-6,9]. This work show aims to study up to which extent the OWF control can be used to minimise the currents flowing through the HVDC-DR station during cable (pole-to-ground) faults. It has been found that substantial current reduction can be achieved and hence, the rating of the ac breaker of the HVDC-DR station can be reduced or even substituted by a no-load switch.

Approach

In order to determine up to which extent the current through the HVDC-DR station can be reduced during cable pole-to-ground faults, the following system is considered, consisting of a 400MW offshore wind farm connected to a HVDC grid with three VSC converters. The wind turbines are based on generators with fully rated converters (type 4):



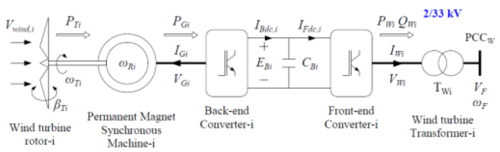


Figure 1: Considered multipoint HVDC system and wind turbine

The distributed protection approach includes a Voltage Dependent Current Order Limit (VDCOL) in each one of the individual wind turbines. When the wind turbines detect a voltage drop on the offshore ac-grid (PCCw), the current references of the wind turbines is reduced to zero. When the currents through the HVDC-DR station are close to zero, the no-load switch of the corresponding pole is opened. Once the no-load switch is opened, then power injection is resumed in the healthy pole.

The proposed approach has been verified by means of detailed simulations using PSCAD, including a clustered model of the wind farm (5 clusters of different power) and a wide frequency model of the cables.

Main body of abstract

The detailed schematic of the HVDC-DR station and its connection to the off-shore point of common coupling (PCCh) is shown in the following figure:

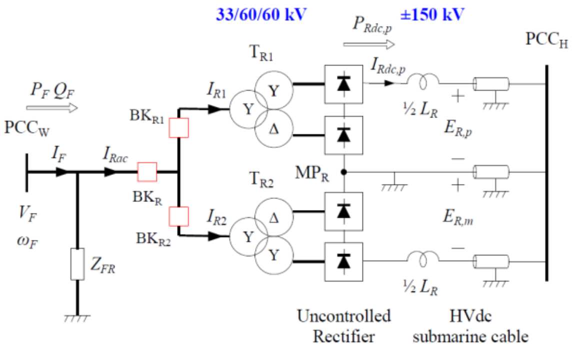


Figure 2: Detailed model of the HVDC-DR station, including filters, no-load switches and cables

The distributed wind farm control is based on a current reference approach [2], where the active current is used to control the ac-grid voltage or power delivered, while the wind turbine reactive current is used to control the off-shore ac-grid frequency:

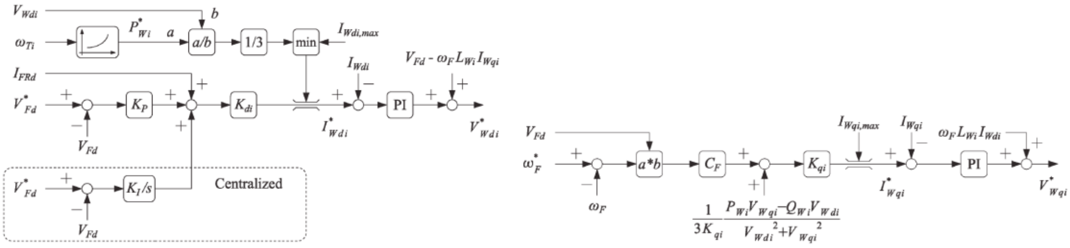


Figure 3: Distributed wind turbine control strategy

In addition to the controls shown in fig. 3, a variable current limit, based on a local measurement of the local voltage vector (Vf) is used to reduce the wind turbine delivered current during faults. In this way, when the magnitude of Vf drops below a certain value, the limits of Iwdi,max and Iwqi,max are reduced, based on local measurements, without the need for communication.

Fig. 4 shows the behaviour of the proposed approach during a short circuit of the positive pole at PCCh (at t=0.1s). Clearly, the voltage of the positive pole goes to zero, while the positive pole current reaches 2.5pu. At this stage, the reduction on the off-shore ac-grid voltage VF is detected by the wind turbines, which immediately limit the active and reactive current references and also reduce the VF reference to zero.

At t=0.2s, the no-load switch BKR1 opens and then power delivery is resumed through the healthy pole.

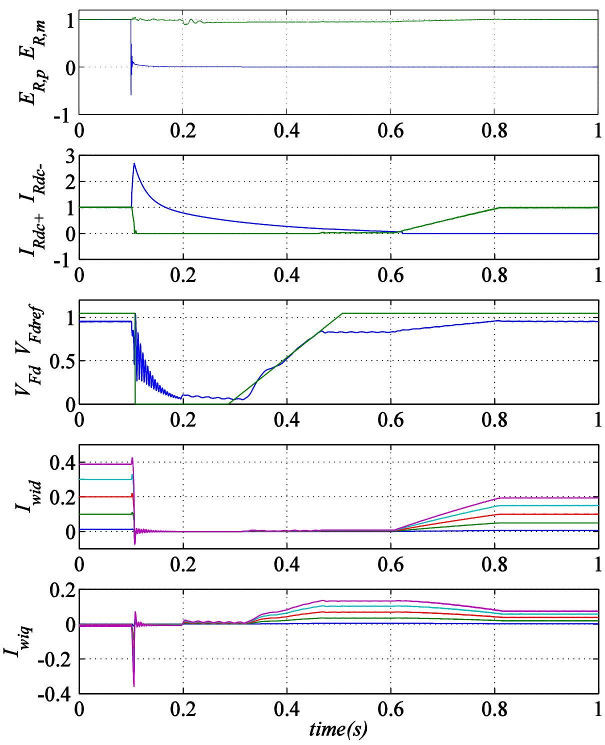


Figure 4. Rectifier and off-shore grid behaviour during fault and recovery

Figure 5 shows the phase currents delivered by the wind farm (IF) and at the input of the HVDC-DR IRac (i.e. past the filters). These graphs show clearly that BKR1 is operated at nearly zero current.

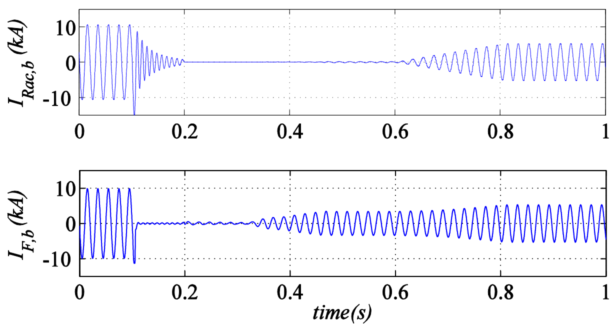


Figure 5. Wind farm and rectifier transformer currents

Figure 5 shows that active power delivery is resumed 0.7s after the fault occurrence, albeit at a reduced level, as now only the negative pole is operational. Note a permanent fault on the positive pole has been assumed. Obviously, full power could be resumed if the positive pole fault is located in a cable segment not directly connected to the HVDC-DR station and the fault is cleared.

Conclusion

This work has studied the possibility of using fast current control on the off-shore wind turbines to reduce short circuit currents through the HVDC-DR during cable faults in multi-terminal HVDC grids.

For the considered 400MW wind farm, it has been found that the proposed approach leads to overcurrents through the HVDC-DR of about 2.5 pu for a period of about 5ms, which is generally considered within the short-time overcurrent capability of diode rectifiers. Afterwards, both ac-side and dc-side currents reduce to zero reasonably fast.

The obtained results suggest that, provided the wind turbine current control is reasonably fast, it might be feasible to substitute the HVDC-DC ac breakers by no-load switches.

Learning objectives

This work shows that fast wind turbine current control can be used to reduce overcurrents during cable pole-to-ground short circuits. Moreover, it shows that the use of no-load switches might be a reasonable alternative to more expensive ac circuit-breakers for the protection of the HVDC-DR station (transformer+DR).

References

[1] Peter Menke, New Grid Access Solutions for offshore wind farms, EWEA Off-shore 2015.

[2] S. Bernal-Perez, S. Añó-Villalba, R. Blasco-Gimenez, N. Aparicio, Connection of off-shore wind power plants to vsc-mtdc networks using hvdc diode-rectifiers, in: Industrial Electronics (ISIE), 2013 IEEE International Symposium on, pp. 1–6. doi:10.1109/ISIE.2013.6563795.

[3] S. Bernal-Pérez, S. Añó-Villalba, R. Blasco-Gimenez, J. Rodriguez-D'Derlée, Off-shore wind farm grid connection using a novel diode rectifier and VSC-inverter based HVDC transmission link, in: IECON 2011 - 37th Annual Conference on IEEE Industrial Electronics Society, pp. 3186–3191. doi:10.1109/IECON.2011.6119820.

[4] R. Blasco-Gimenez, S. Añó-Villalba, J. Rodríguez-D'Derlée, F. Morant, S. Bernal-Pérez, Distributed voltage and frequency control of offshore wind farms connected with a Diode-Based HVdc link Power Electronics, IEEE Transactions on 25 (2010) 3095–3105. doi:10.1109/TPEL.2010.2086491.

[5] R. Blasco-Gimenez, S. Añó-Villalba, J. Rodriguez-D'Derlée, S. Bernal- Pérez, F. Morant, Diode-Based HVdc link for the connection of large offshore wind farms, Energy Conversion, IEEE Transactions on 26 (2011) 615–626. doi:10.1109/TEC.2011.2114886.

[6] J. Bowles, Multiterminal HVDC transmission systems incorporating diode rectifier stations, Power Apparatus and Systems, IEEE Transactions on PAS-100 (1981) 1674–1678. doi:10.1109/TPAS.1981.316562.

[7] M.K. Bucher, M.M. Walter, M. Pfeiffer, C. Franck, Options for ground fault clearance in hvdc offshore networks, in: Energy Conversion Congress and Exposition (ECCE), 2012 IEEE, pp. 2880–2887. doi:10.1109/ECCE.2012.6342371.

[8] M. Callavik, A. Blomberg, J. Häfner, B. Jacobson, The hybrid hvdc breaker. an innovation breakthrough enabling reliable hvdc grids, ABB Grid Systems, Technical Paper Nov'2012 (2012) 1–10.

[9] T. Machida, I. Ishikawa, E. Okada, E. Karasawa, Control and protection of HVDC systems with diode valve converter, Name: Electr. Eng. Jpn.(Engl. Transl) (1978).