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Christian Feltes

Advanced Fault Ride-Through Control of DFIG based Wind Turbines including Grid Connection via VSC-HVDC

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Internet: www.shaker.de • e-mail: info@shaker.de

In the recent years there has been an extensive growth in the renewable energy sector all over the world. In this regard the wind energy seems to be one of the most promising renewable resources, since it combines relatively high efficiency with moderate costs. With the growing renewable energy share in the power generation mix it becomes inevitable that also these new generation technologies participate on the provision of grid services to guarantee stable operation of the grid, especially when one considers the decreasing number of conventional power plants in operation as a result of the expansion of wind based generation plants. These so-called ancillary services include frequency / active power control, voltage / reactive power control and fault ride-through (FRT) with fast voltage control and are stipulated in modern grid codes.

In the context of this thesis advanced control algorithms have been developed for wind turbines based on doubly-fed induction generator (DFIG) to allow safe FRT during symmetrical and unsymmetrical faults. This covers the control for conventional AC grid connection as well as for the connection through voltage source converter (VSC) based high voltage direct current transmission (HVDC).

Currently, the DFIG is the most used generator technology in modern wind turbines, since it combines a relatively simple slip-ring induction machine with a frequency converter rated to only approx. 30% of the total power. This makes the DFIG a cost-effective concept, which offers a variable speed range and a high degree of flexibility in control. However, due to the direct coupling of the generator stator circuit to the grid, grid faults are a special challenge for the frequency converter, its protection circuits and control algorithms. As base for the detailed evaluation of the impact of grid faults to the DFIG, this thesis contains the analytical derivation of the DFIG short circuit currents under consideration of frequency converter control. The DFIG concept presented in this thesis makes use of a DC chopper in the frequency converter, which allows safe FRT with grid voltage support through both converter sides. The developed control contains a new algorithm for a clear separation and control of positive and negative sequence components as well as other selected frequency components. The implemented method can be utilized to enhance the power quality within the grid during voltage imbalances or increased harmonic levels. Furthermore, special control algorithms have been developed in this thesis, allowing the optimal voltage support during grid faults by an intelligent distribution of the reactive current injection across both converter sides even for extremely deep voltage sags. In this way it can be ensured that wind turbines inject a defined fault current, which is required for selective fault detection and tripping of the faulty elements.

Another important topic in this dissertation is the development of a new coordinated control concept for DFIG based wind farms connected to VSC-HVDC. This method allows FRT during onshore grid faults without the need for a DC chopper within the HVDC link. The introduced algorithm uses the wind farm side HVDC converter to apply a controlled voltage drop in the wind farm grid with suppression of the DC components in the DFIG currents. With this method the wind farm output power can be reduced rapidly and the HVDC is protected against overvoltages in the DC circuit. At the same time the controlled suppression of the DC current components reduces the stress to the power electronics and the drive train of the wind turbines.