Abstract

Doubly fed induction generator (DFIG) with fractionally rated back-to-back voltage source converters (VSC) connected between its rotor and stator terminals is the most popular Variable Speed Constant Frequency (VSCF) Wind Energy Conversion System (WECS) with a market share of above 50% at present. This popularity derives from its superior performance, lower cost, and control flexibility. A Matrix Converter (MC) can be a good alternative to the back-to-back converter in this application due to its compact size, increased efficiency and longer life span. However, there are several issues concerning the control of an MC fed DFIG based VSCF WECS which have to be solved before this topology gains commercial acceptance. These include complicated modulation algorithm, control complexity due to coupling between active and reactive power transfer, high grid current distortion due to MC input filter resonance, limited reactive power support, fault ride through capability, operation from unbalanced grid etc.

The present research work is carried out to develop a suitable controller for a grid connected MC fed DFIG based VSCF WECS which solves some of the above mentioned problems with minimum control complexity. The control algorithm is realized using a modified look-up table based DTC controller, which offers superior dynamic, and steady state DFIG torque response compared to the existing control algorithms. The superior performance of the proposed controller is experimentally validated on a laboratory prototype system.

A double-loop control structure for controlling the MC input reactive power is chosen after a comparative study with a single loop structure. Further, a novel rotor flux based active damping mechanism is proposed which augments the basic DTC algorithm to mitigate the problem of resonance at the MC input filter excited by the PWM input current of the MC. A small signal model of the MC input filter system along with the active damping controller is developed to aid the design of the later and to study the effect of different system parameters and operating conditions on its performance. Experimental results obtained from the laboratory prototype confirm the efficacy of the proposed active damping algorithm in improving the quality of the MC filter input current. The predictions from the small signal model are also experimentally verified.

Next a “predictive DTC algorithm” for the MC fed DFIG is proposed which retains all the advantages (i.e. fast torque response, decoupled active-reactive power control, active damping of the MC input filter) of the previously proposed controller while extending the reactive power supply range of the system. This is achieved by judiciously utilizing all the available switching states of the MC. The MC switching states are selected using the input filter model and the remaining control tasks (i.e. machine control and active damping) are performed by the DTC algorithm. So the machine dynamic performance remains the same as that of a DTC based controller while higher numbers of available switching states increase the MC input reactive power capability. As before, all analytical predictions are supported by experimental results.

Finally, an algorithm based on the system loss model is developed which maximizes the generating system efficiency while regulating the grid power factor to the desired value. To this end a new equivalent circuit based procedure for calculating the maximum reactive power capability of the MC under different operating conditions is proposed and experimentally verified. The algorithm developed is simple enough (require less computation) to be implemented online for system level control of wind farms by setting different reactive power references to individual generators. A generalized active-reactive power capability curve (similar to the operating chart of a synchronous generator) for a typical large wind turbine driven MC fed DFIG system is also derived using the same algorithm.

Key words: Double Fed Induction Generator (DFIG), Matrix Converter, Direct Torque Control (DTC), Active Damping, Predictive Control, Loss Minimization, Reactive Power Control, Variable Speed Constant Frequency (VSCF), Wind Energy.