Abstract

Recently, there has been an increasing demand of high power (multi-megawatt) converters in various application fields such as, Industrial Drives, Renewable Power Generators, Power Factor Correctors (PFCs) etc. These converters are mostly connected to the medium voltage (2.3, 3.3, 4.16, or 6.6kV) AC network. In such cases, multilevel voltage source converters are being preferred over two-level converters (with series-connected devices) for their well-known advantages such as, reduced device voltage rating, lower harmonic content in the line-to-line voltage, lower dv/dt (hence, reduced electromagnetic interference) etc. There are some applications where active power flows only from the ac side to the dc side. Examples of such applications are (a) power supplies for telecommunications, aircraft, naval propulsion systems, X-ray, (b) pumps and blowers requiring no regenerative braking, (c) the machine-side converter for wind energy conversion systems, etc. In such applications, reduced-switch non-regenerative rectifiers are preferred as they reduce circuit complexity and cost while enhancing their power density and reliability.

In this thesis, the limitations of the existing reduced-switch unidirectional rectifiers in high power medium voltage (requiring five or more voltage levels) applications are first highlighted. Then, two new reduced-switch AC to DC converter topologies which are suitable for medium voltage (MV) high power applications are proposed. These rectifiers require fewer numbers of active switches and associated gate drivers. Also, they do not require any extra hardware circuitry for balancing various capacitor voltages which reduces hardware complexity, cost and increases power density and reliability of the system. Principles of operation of these circuits along with their switching cycle average models are explained. A hybrid modulation strategy suitable for these rectifiers is also presented which uses level-shifted and phase-shifted carriers. Thereafter, an input voltage sensorless control strategy, suitable for these types of unidirectional rectifiers, is proposed. It ensures unity terminal displacement factor which further increases the power density of the converter. Detailed dynamic modeling of the system along with the stability and parameter sensitivity analysis are presented. In order to reduce the switching losses and thereby increasing the overall system efficiency, two Discontinuous Pulse Width Modulation (DPWM) techniques are proposed in this work. The implementation of the proposed DPWM methods (DPWMA, DPWMB) is shown to be simple with very few computations when various symmetries of the space vector diagram of the rectifier are properly exploited. The effectiveness of these DPWM strategies, in terms of several converter performance parameters (such as, switching loss, DC-link mid-point ripple, RMS flying capacitor currents etc.), is analytically established. One of the proposed rectifiers is then used in a Permanent Magnet Synchronous Generator (PWSG) based Wind Energy Conversion System (WECS). A new mechanical sensorless control strategy including Maximum Power Point Tracking (MPPT) for the WECS is also proposed.

The performance of the proposed rectifier topologies along with their modulation and control techniques are validated using experimental results obtained from the laboratory prototypes against analytical predictions.

Keywords: AC-DC converters, Multilevel converter, Flying capacitor (FC), Neutral point clamped (NPC), unity power factor (upf) rectifier, Discontinuous PWM, Wind Energy Conversion System (WECS), Permanent Magnet Synchronous Generator (PMSG), Sensorless control.