CHAPTER 6

CONCLUSIONS AND FUTURE WORK

The main results and contributions of the dissertation are summarized as follows:

The general topological concept of quasi-single-stage (QSS) isolated power conversion is introduced and defined. The family of QSS power converters feature single-stage power processing without a dc-link low-pass filter, a unidirectional pulsating dc-link voltage, soft-switching capability with minimal extra commutation circuitry, simple PWM control, and high efficiency and reliability. Some non-isolated QSS power conversion examples including three-phase buck rectifier, VSI/CSR, and matrix converter are given.

In chapter 3, a new soft-switched single-phase quasi-single-stage (QSS) bi-directional inverter/rectifier (charger) topology is derived based on the QSS power conversion concept elaborated in Chapter 2. It is functionally equivalent to the single-stage, cycloconverter-based topology, yet performance-wise, superior to the latter. A simple active voltage clamp branch is used to clamp the otherwise high transient voltage on the current-fed ac side, which is caused by the unavoidable leakage inductance of the transformer, and at the same time, to achieve ZVS for the switches in the output side bridge. Seamless four-quadrant operation in the inverter mode, and rectifier operation with unity power factor in the charger (rectifier) mode are realized with the proposed uni-polar center-aligned PWM scheme. Single-stage power conversion, standard half-bridge connection of devices, soft-switching for all the power devices, low conduction loss, simple center-aligned PWM control, and high reliability and efficiency are among its salient features. Experimental results on a 3 kVA bi-directional inverter/rectifier prototype validate the reliable operation of the circuit.

The proposed basic QSS inverter/rectifier topology can also be extended to include other single-phase topologies, such as the inverter/rectifier with a full-bridge primary circuit, and the three-phase bi-directional inverter/rectifier. In the three phase case, a QSS isolated three-phase ZVS boost rectifier can be easily obtained by replacing the dc-side switches with diode rectifiers in the bi-directional topology.

The circuits in this family all involve the isolated boost operation when the power is enforced to flow from the current-fed side to the voltage-fed side. Although with a simple active voltage clamp branch, the transient voltage can be effectively suppressed theoretically, the voltage overhead necessary on the clamp capacitor, and the transient voltage induced by the parasitic inductance in the layout may limit their applications in high-voltage off-line applications, e.g. in the case of a 480 V three-phase ac supply.

A new QSS isolated three-phase ZVZCS buck PWM rectifier for high-power off-line applications is proposed in Chapter 4. It consists of a three-phase buck bridge switching under zero current and a phase-shift-controlled full-bridge with ZVZCS, while no intermediate dc-link is involved. Input power and displacement factor control, input current shaping, tight output voltage regulation, high-frequency transformer isolation, and soft-switching for all the power devices are realized in a unified single stage. Because of ZVZCS operation, it can work at high switching frequency while maintaining reliable operation and achieving higher efficiency than that with standard two-stage approaches.

The general topological concept of ZVZCS full-bridge dc-dc converters is also introduced, and possible implementations summarized. The concept is then extended to the case of QSS isolated three-phase buck PWM rectifier to obtain a family of isolated ZVZCS buck rectifiers. The circuits in the family all feature a pulsating dc-link, hybrid ZVZCS operation, global soft-switching capability, and relatively simple implementation. Simulation results validate the principles of operation of these circuit topologies.

The concept of charge control (or instantaneous average current control) of three-phase buck PWM rectifiers is introduced in Chapter 5. It controls precisely the average input phase currents to track the input phase voltages by sensing and integrating only the dc rail current, realizes six-step PWM, and features simple implementation, fast dynamic response, excellent noise immunity, and is easy to realize with analog circuitry or to integrate. One particular merit of the scheme is its capability to correct any duty-cycle distortion incurred on only one of the two duty-cycles which often happens in the soft-switched buck rectifier topologies because of the intervention of the soft-switching action. Another merit with this scheme which is practically important is the smooth transition of the input currents between the 60^{o} sector boundaries because the charge controller is always reset in every switching cycle. The concept, implementation, and design guidelines are addressed. Simulation and preliminary experimental results show that smooth operations and high quality sinusoidal input currents in the full line cycle can be achieved. The proposed control scheme can be easily extended to realize different PWM patterns, and to control various three-phase buck rectifier-based systems.

Future work can be directed to the exploration of the performance limitation of the QSS isolated ZVZCS rectifiers proposed in Chapter 4 under distorted and/or unbalanced line conditions. The experimental verification of the charge control applied to the case of

QSS isolated ZVZCS buck rectifiers is of practical importance, and deserves further works in that direction.