

6. CONCLUSION

6.1 SUMMARY

In summary, the following original contributions have been made in this study of the voltage stabilization techniques for flying capacitors used in soft-switching multilevel active power filter applications. A comprehensive literature survey was performed and tasks to be performed in this dissertation were identified. The author believes that the contributions of this work are:

- (i) A comprehensive literature survey has been performed on harmonic quality, multilevel active filters, soft-switching techniques, control issues, and fundamental issues of the flying capacitor multilevel converters. The major issue of voltage balancing between the flying capacitors for safe operation was investigated in depth.
- (ii) A new soft-switching flying capacitor multilevel inverter topology has been proposed and verified through simulation and experiment. The proposed inverter used a ZVT soft-switching circuitry with inductor coupling, in which the auxiliary devices have less voltage and current ratings. Thus, the inverter has the advantages of lower voltage and current ratings for auxiliary switches and diodes, achieved by using a coupled inductor and midpoint rail between the DC capacitors. Simulation and experimental results indicated that the inverter achieved zero-voltage condition in all of the main switches and zero-current turn-off of the auxiliary switches during the commutation processes.

- (iii) Fundamentals of flying capacitor voltage balancing used in the proposed inverter were characterized and studied. The various aspects associated with voltage balancing were investigated to identify their safe operation. The following results were obtained in this study.
- Identification of the fundamentals of voltage unbalance between flying capacitors and dc link split capacitors;
 - Analysis of the clamping mechanism with flying capacitors;
 - Voltage synthesizing modulation for the charge balancing between the flying capacitors;
 - Characteristics and dynamics of flying capacitors under various operations; and
 - Interaction between the flying capacitors, snubbing capacitor, and dc capacitors during reactive power compensation.
- (iv) An overall control algorithm for a new soft-switching multilevel active power filter have been proposed and discussed. For voltage balancing under the capacitor voltage unbalance, a phase-shift feedback control algorithm was proposed and theoretically explained, based on instantaneous reactive power theory. Various dynamic behaviors of voltage balancing in the active filter were studied and verified by simulation results including gain and phase magnitude of the controller. With relation to high performance controls, stability of the converter in transient and steady state conditions were also characterized by the interaction between control feasibility and influences of the proposed soft-switching multilevel active filter.
- (v) A new voltage controller has been proposed and implemented for voltage balancing with the overall control algorithm. The simulation and experiment indicate that the proposed controller can compensate the source current to be sinusoidal and balanced to maintain the constant capacitor voltage. With relation

to transient responses, the controller at transient and steady state conditions was also characterized by the interaction between control feasibility and influences of the active filter.

6.2 FURTHER RECOMMENDATIONS

As problems caused by the non-linear load become increasingly obvious, utilities are faced with a need to reduce harmonics. Thus, there has been an increasing interest in soft-switching active power filter technologies in order to improve power quality and reduce switching stress.

Based on the work accomplished in this dissertation, the author recommends the following tasks for possible future work:

- Identification of voltage drift problems associated with increased voltage levels;
- Control feasibility and influences of voltage balancing behaviors;
- Optimization of a soft-switching circuit with inductor coupling; and
- Comparison of various multilevel active power filter topologies.