Study of Three-Level Hybrid Active Power Filter with Quasi-Resonant DC-Link Technique in Three-Phase Four-Wire System

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Master of Science in Electrical and Electronics Engineering

12/2013

Faculty of Science and Technology
University of Macau

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A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science in Electrical and Electronics Engineering

Faculty of Science and Technology
University of Macau

12/2013

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Abstract

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Hybrid active power filter (HAPF) has become a more and more important power quality compensator in the past two decades. Due to the development of power electronic devices and equipments in distribution system, power quality issues such as harmonic currents and reactive power produced by nonlinear loads are increasing. They pollute the power system and induce a lot of electricity safety problems, thus creating a desperate need for power compensators to solve these power quality problems. Actually, hybrid active power filter is a combined system of active power filter (APF) and passive filter (PF), both of which are able to eliminate harmonic currents and reactive power. However, their inherent limitations bring about their shortcomings, whereas hybrid active power filter is a way to overcome these disadvantages as it has the capability of anti-resonance and a low power rating.

Soft-Switching Technique is employed to solve the switching transition problems of power devices, as high voltage and current stress cause high switching loss, high system loss and low system efficiency. As a result, soft-switching circuits can not only reduce switching loss but also release voltage and current stress; moreover, they can also reduce the changing rate of voltage and current of power switches, i.e., dv/dt and di/dt, which is the cause of electromagnetic interference (EMI). Quasi-Resonant DC-Link (QRDCL) Inverter is a useful topology of soft-switching circuit integrated into the inverter to achieve soft-switching operation. This topology has been already applied in two-level and three-level inverters for ten years due to its obvious

advantages: less auxiliary switches, lower voltage rating and a simple control method. Therefore, with the quasi-resonant dc-link circuit, the converter has the ability to reduce switching loss and improve system efficiency.

The proposed topology is a three-level hybrid active power filter combined with quasi-resonant dc-link circuits in three-phase four-wire system. As is discussed above, this three-level quasi-resonant dc-link hybrid active power filter can achieve both advantages of hybrid active power filter and quasi-resonant dc-link technique: to compensate for harmonic currents and reactive power with a low dc voltage, and reduce switching loss and release voltage and current stress. Meanwhile, the multilevel inverter can reduce voltage stress across switches in high voltage application, and provide more available vector for selecting appropriate switching vectors to reduce output harmonic components. In this thesis, the mathematical models are presented of quasi-resonant dc-link circuits, three-level active power filter and three-level quasi-resonant dc-link hybrid active power filter. Furthermore, a comparison is made between the three-level active power filter, the three-level quasi-resonant dc-link active power filter and the proposed three-level quasi-resonant dc-link hybrid active power filter. Then, the proposed topology is studied and analyzed in terms of the operational principle, the control system and the design of system parameters. The well-known instantaneous reactive power theory, which has been applied in many power compensators, is employed in the control system of the proposed topology. Three dimensional direct pulse width modulation is applied since it is easy to manipulate and requires low computation. The zero voltage switching controller is used to coordinate with PWM inverter. Along with the operation of quasi-resonant dc-link circuits by a fixed delay time, they achieve zero voltage switching for the main devices of the inverter. At the same time, the effect of zero voltage switching is taken into consideration, as they will affect pulse width of the inverter so that its compensating performance will be degraded.

Finally, simulation results are given to verify the validity of the proposed topology. It’s proved that the proposed three-level hybrid active power filter with quasi-resonant dc-link circuits can reduce switching loss and improve system efficiency, and the

compensating results are also accepted. Then, simulation comparison between active power filter, hybrid active power filter and soft-switching hybrid active power filter is made. A discussion of the proposed quasi-resonant dc-link hybrid active power filter is conducted as to its different ratios including the resonant period and the switching period, and its performance with varied loads.

Key words: hybrid active power filter, quasi-resonant dc-link, soft-switching, zero voltage switching.

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GLOSSARY

3-D. Three-dimensional

APF. Active Power Filter

AC. Alternating Current

DC. Direct Current

DFACTS. Distribution Flexible AC Transmission System

DVR. Dynamic Voltage Restorer

EMI. Electro-magnetic Interference

FACTS. Flexible AC Transmission System

HAPF. Hybrid Active Power Filter

IGBT. Insulated Gate Bipolar Transistor

NBARC. Negative-Bus Auxiliary Resonant Circuit

NPC. Neutral Point Clamped

PF. Power Factor

PWM. Pulse Width Modulation

QRDCL. Quasi-Resonant DC-Link

SVM. Space Vector Modulation

TDD. Total Demand Distortion

THD. Total Harmonic Distortion

UPQC. Unified Power Quality Conditioner

VSI. Voltage Source Inverter

ZCS. Zero Current Switching

ZVS. Zero Voltage Switching

ACKNOWLEDGMENTS

I would like hereby to thank so many people on my completion of the thesis. Without their kind help to my study and research, it would have been difficult for me to accomplish such a challenging task as writing my dissertation. I sincerely appreciate the instruction, supervision and selfless support given to me by my supervisor, Prof. Man-Chung Wong, and Dr. Ning-Yi Dai and Dr. Chi-Kong Wong. I would also like to express my gratitude to Research Committee (RC) of University of Macau and the Science and Technology Development Fund (FDCT) of Macau Government for their financial support to my study for master degree. My gratitude also goes to all the people in the Power Electronic Laboratory at the University of Macau, Mr. Io-Keong Lok, Dr. Chi-Seng Lam, Mr. Sun Bo, Mr. Cui Xiao-Xi, Mr. Keng-Weng Lao, Mr. Wai-Hei Choi and Mr. Chen-Pei Zheng as they've given me so much advice and help. Last but not the least, I would like to say "thank you" to my parents for their selfless love, support, and encouragement for me through all the years in my life.