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Abstract

ANALYSIS AND EVALUATION OF SOFT-SWITCHING TECHNIQUES FOR 3-PHASE 4-WIRE SHUNT POWER QUALITY COMPENSATORS

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Due to the development of "Custom Power" concept, 3-phase 4-wire system will play an important role in the distribution site. And with more non-linear load applications, power quality is a serious issue under the "Custom Power" concept. Shunt active power filter as one of the power quality compensator could compensate harmonics, reactive power, unbalance as well as neutral current in the 3-phase 4-wire system. However, in the practical application, shunt power quality compensator has the disadvantages: mass switching losses, serious electro magnetic interference (EMI) problems and low switching frequency. In the past two decades, soft-switching techniques have attracted more and more attentions for their advantages: higher switching frequency, lower switching losses, and alleviated EMI problems (lower dv/dt and di/dt). Soft-switching techniques can create zero voltage switching (ZVS) and/or zero current switching (ZCS) which stagger the voltage and current of the switch during the turn-on and turn-off of switching, hence, the switching losses are virtually eliminated and the higher switching frequency is attainable. In this thesis, the researches are mainly focused on the influence of soft-switching inverter techniques on the shunt power quality compensator application in the 3-pahse 4-wire system.

Soft-switching inverter techniques can be generally divided into two fields: one is DC side and the other is AC side. For the DC side, RDCLI, ACRDCLI and QRDCLI are generally introduced as well as the QRCMI, ARCPI and SSZCTI for the AC side. The different soft-switching topologies are compared in terms of typical power level,

number of devices, device voltage & current stresses, control strategy, etc. Quasi-resonant DC link (QRDCL) topology, as one of DC link soft-switching circuits, is adopted to investigate the influences of soft-switching techniques on the shunt power quality compensator due to its variable zero-voltage instant and variable zero-voltage interval which enhances the pulse width modulation (PWM) ability greatly. Evolved from 3-leg inverter structure in the 3-phase 3-wire system, 3-leg center-spilt inverter structure is used in the 3-phase 4-wire system and 3-dimensional PWM (3DPWM) consisted of mainly the 3-dimesional sign cubical hysteresis (3DSCH) current control, 3-dimensional cylindrical coordinate control and 3-dimesional space vector modulation (3DSVM) is developed from 2DPWM with respect to the existence of neutral line. Since 3DSCH has the easy control with inferior performance compared with the complicate control and superior performance of 3DSVM and the 3-dimension cylindrical coordinate control is just among previous two cases, hence, the 3DSCH and 3DSVM are the usual cases. Based on 3DPWM, novel controls are proposed to match the conventional inverter modulation and the auxiliary soft-switching control, respectively. For the 3DSCH, time sequence matching is made with time delay through detecting the rising edge of switching. While for 3DSVM, since the voltage-second reference can be approximated by a sequence of voltage-second states and the duration of each switching mode and the DC link voltage are the two main elements to influence the voltage-second reference. Therefore, transferring error conducting time and increasing DC voltage are used to compensate soft-switching zero voltage time influence on the integrated vector in the cases of under-modulation and over-modulation respectively.

Simulation results verify the correctness of the proposed control methods and show that the switching frequency is increased to over ten kilohertz and the switching losses are reduced obviously. Experiment results indicate that the harmonic, reactive and neutral currents can be compensated simultaneously by using the implemented shunt power quality compensator. Without the QRDCL added, masses of switching losses occur; with the addition of QRDCL, the switching losses are obviously reduced, but the

compensation effect becomes worse due to the influence of zero-voltage time, whereas, the compensation performance is improved with the proposed control.

Key words: soft-switching, QRDCL, power quality, 3DPWM, 3-phase 4-wire system