Control Parameter Selection in Auxiliary Resonant Commutated Pole Converters

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Abstract—This paper addresses the optimum selection of the boost current and threshold current control parameters for the ARCP soft switching technique. The parameters are derived based on a minimization of the output voltage distortion induced by the ARCP operation. The impact of the proper selection of the resonant parameters on the system design is discussed.

I. INTRODUCTION

The Auxiliary Resonant Commutated Pole (ARCP) soft switching technique has been discussed extensively in the literature in past years. After having been proposed as a replacement for conventional snubber circuits in Voltage Source Inverters (VSI) in 1983 [1], this soft switching technique has been investigated and extended in [2] and [3]. Subsequently, numerous papers have treated practical and theoretical aspects of the ARCPVSI.

The driving forces for the continuation of the research effort are the excellent characteristics of this soft switching technique. A few of these are: i) no additional devices in the main current path, ii) the blocking voltage rating of the main switches is not influenced by the quasi-resonant commutation, iii) the dv/dt across the devices and at the inverter terminals is controllable, simplifying series connections and/or making dv/dt limiters redundant, and iv) all main switches operate in Zero Voltage Switching (ZVS) mode and all auxiliary switches operate in Zero Current Switching (ZCS) mode resulting in low switching losses. Drawbacks and remaining problems include the high number of additional devices, complexity of control, voltage spikes at reverse recovery turn-off during ZCS operation, and the center-point stability of the dc-link capacitors.

The proper design of the resonant components and control parameters as well as the mechanical set-up of the converter are crucial for a successful ARCP operation. While the selection of the resonant inductor and snubber capacitor values is typically based on loss considerations and/or the maximum allowable dv/dt at the device or the converter, the optimum selection of the control parameters for the quasi-resonant commutation has been addressed only minimally. Two different boost current values and one threshold current value at which the operation mode of the converter is changed must be adjusted. These parameters have a significant impact on converter losses, stability of operation, output voltage quality and maximum transfer ratio.

The objective of this paper is to provide an analytical investigation of the optimum selection of these parameters. After a brief introduction of the ARCP principle, transfer ratio limits and output voltage deviation due to the resonant commutations are reviewed. The optimum selection of the control parameters based on a minimum output voltage distortion is discussed for two different control modes. The influence of the ac resistance and the diode reverse recovery current is addressed. The system is represented in p.u. parameters to achieve a universally applicable description independent of the power level. In addition to this, the importance of the proper parameter selection is shown in an example design of a dc/ac, three-phase ARCPVSI (400V, 100kVA). The analytical investigations have been verified by digital simulation.

II. REVIEW OF GENERIC ARCP CELLS

The equivalent circuit of the ARCP cell is shown in Fig. 1. The principles of operation for the generic two-level ARCPVSI (Fig. 1) have been discussed extensively in the literature [2], [3]. Unless otherwise stated the analysis to follow assumes ideal switches, negligible circuit parasitics and a balanced dc-link center point. The commutation quantities $i_o$ and $V_{dc}$ are assumed to be constant within one period of the switching cycle $T_s$. Three different commutation types require a separate description: i) the ARCP commutation, ii) the capacitive or forced commutation, and iii) the ARCP supported capacitive commutation.

![Fig. 1 Generic ARCP commutation cell](image-url)