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Investigation and Evaluation of Multilevel H- NPC Converter for Electrically Driven Trains

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Abstract. In this paper is analyzed and simulated on the computer the operation of a three level H-bridge converter as well as its parallel operations. Based on the simulation results the operating behavior between a) a three level H-bridge neutral point clamped converter, b) a three level H-bridge neutral point clamped converter with parallel elements and c) two three level H-bridge neutral point clamped converters parallel connected is being compared. From the simulation results is obvious that in the first two cases the ripples, the distortion in primary and secondary winding currents, and the power factor are quite satisfactory and almost identical to each other. In the third case as compared with the first two, we observe that current harmonics with higher amplitude appear in the primary winding of the transformer.

Key words

AC-DC Single-Phase converter, Modulation Strategy, Three level H-NPC topologies, Grid connected converter.

1. Introduction

AC-DC converters can be separated into converters which operate with low transition frequency and into converters with high transition frequency. The main disadvantage of these converters is the derivation of harmonics and reactive power [1], [2].

Harmonics have a negative impact on electrical power system operation, so particular attention to their generation and elimination is paid. Specifically, many international standards have introduced significant and strict limits on the harmonics which injected to the electrical power system [3].

A conventional method for harmonic elimination of the input currents is the usage of converters with high switching frequency. A further improvement is the usage of passive filters [4]. Over the last decade, active power filters have emerged for elimination of harmonics which are injected to the grid [5], [6].

A variant way to harmonic elimination is the power factor correction (PFC) [7]. With this method harmonics are eliminated and thus the power factor is improved, that is why they get this name. There are many applications where the power flow can be reversed during operation. Such examples are the driving systems in electric traction. Converters which operate in four quadrants with a high power factor are named active front end (AFE) converters, which can be classified into voltage source converters (VSC) and static var compensator (SVC) [8]. In electric traction the conventional circuit of a two level PWM converter is applied [9], [10]. In this case a unipolar PWM strategy of asymmetric samples is espoused for the converter.

Furthermore, in electric traction circuits three level PWM converters are applied. These converters have eight switching modules with eight anti-parallel diodes and four clamping diodes. The modules S_1, S_2, S_3 and S_6 switched on with 180° phase shifting compared to S_3, S_4, S_7 and S_8 respectively. Therefore, there are only four independent modules which have sixteen switching states. If the modules S_1, S_4, S_5 and S_8 are selected as the four independent, the rest modules are the dependent modules. Since the modules S_1 and S_4, or S_5, S_8 cannot switch on simultaneously there are seven redundant switching states. In conclusion, there are only nine valid switching states. Considering the cases for both positive and negative current flow, we end up with eighteen valid switching states for a three level PWM converter [11].

In recent years many research efforts are made to implement in the electric traction chain multilevel converters which are based on the cascaded connection of independently supplied single phase converters. These arrangements not only allow the connection at very high voltage levels with conventional semiconductor elements, but also the current which is generated in the secondary winding of the transformer has low harmonic content. In this case installing additional dc-dc converters allow the power exchange with the common output side [12].