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On Design of a Compact Primary Switched Conversion System for Electric Railway Propulsion

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Abstract

In this thesis, a compact and light primary switched conversion system for AC-fed railway propulsion is investigated. It is characterized by soft switching of all converter stages and a source commutated primary converter comprising series connected valves. Both weight and volume of the conversion system are reduced significantly compared to a conventional system with a low frequency transformer.

The conversion system is made up of *N* isolated AC/DC conversion cells, each comprising a cycloconverter and a voltage source converter (VSC) coupled by a medium frequency transformer. The cells are series connected on the AC side and connected to a common DC-link. Thus, *N+1* voltage levels can be synthesized at the AC terminal and the voltage stress on the transformer and line filter is reduced compared to a one cell solution. Series connection of semiconductor valves allows independent choice of blocking voltage and number of converter cells. Choosing two converter cells is an attractive compromise. Five level output reduces the harmonic distortion and simplify transformer and line filter design while keeping the complexity of the conversion system low.

The mutually commutated converter (MCC) allows a transformer frequency in the range of 4 to 8 kHz without derating the line side converter due to zero voltage switching of the VSC. Modern magnetic materials, like high silicon steel, amorphous and noncrystalline materials allow design of the transformer with high efficiency at elevated frequencies.

In a 15 kV system, the peak voltage at the catenary is typically beyond 32 kV which is far beyond the voltage capability of currently available semiconductors. Therefore, several semiconductors are connected in series. Favourable commutation conditions and a new gate drive arrangement allow snubberless commutation of the primary converter stage. Thus, the primary converter can be highly integrated, reducing both weight and volume. The conversion system can be placed on the roof or in the underframe without compromising efficiency or vehicle performance.

The feasibility of the conversion concept has been demonstrated by means of a down-scaled prototype. Snubberless commutation of series connected valves is demonstrated.

Keywords: Isolated AC/DC Converter, Mutual Commutation, Soft Switching, Cycloconverter, Medium-Frequency Transformer, Electric Railway Propulsion