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Direct Voltage-sourced Matrix Converter

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Summary

The monograph is devoted to classical scheme of direct matrix converter with three phase output and its topology modification such as capacitor clamped multilevel matrix converter, dual matrix converter and matrix rectifier.

Semiconductor part of matrix converter is a matrix of nine bidirectional switches, through which each output phase can be connected with the selected input terminal. Direct energy conversion is realized in tested converter and either AC/AC or AC/DC conversion may be performed. The capability to obtain both zero, leading or lagging input displacement factor is the crucial advantage of the direct matrix converter.

One of the limitations of the direct matrix converter is the fact that value of voltage transfer ratio is less than one. Apart from that, synthesized output and input waveforms are accompanied by the emergence of high frequency distortion components, with frequency dependent on switching frequency in matrix converter. The use of high switching frequency may causes specific disturbances called common mode voltage. The common mode voltage problem concerns every converter controlled with PWM method.

In reference to limitations, which result from the specific manner of matrix converter operation, the possibilities of elimination of the limitations on synthesized voltage and current waveforms have been analysed. For that purpose an analysis with regard to content of distortion components in synthesized voltage and current waveforms has been made. The analysis was performed with the use of double Fourier series. The results allow to conclude that in classic symmetrical three phase to three phase matrix converter the output voltage waveforms contain both basic and high frequency components. These high frequency components are distortion components situated as sidebands about switching frequency and its harmonics.

Simultaneously, the Fourier analysis of switch current has shown that waveform of this current apart from high frequency components contain low frequency components. Frequencies of these low frequency components correspond appropriately to input voltage frequency, output voltage frequency and linear combination of both input and output voltage frequency. Contribution of the low frequency components depends on input displacement angle. Performed switch current Fourier analysis allows to formulate conclusions that for asymmetry in supply or in control of matrix converter switch the low frequency components, whose frequency is equal to a linear combination of input and output frequency, appears in input or output current as a component distorting their waveforms.

The results of input current, output current and switch current spectrum harmonic analysis allow also explaining the phenomenon of matrix converter control with input displacement angle different than output load displacement angle. It confirms the observation that matrix converter establishes a reactive power exchange between the load phases and also reactive power exchange takes place between the input phases via the switches of the matrix converter.

The next problem connected with Fourier analysis applied to waveforms synthesized in matrix converter is search for possibility to eliminate high frequency components or at least to increase their frequency. The problem has been analysed with an example of capacitor clamped multilevel matrix converter. It has been observed that in multilevel topology of matrix converter it is possible to increase frequency of high frequency distortion components of output voltage and eliminate groups of distortion components corresponding to odd harmonics of switching frequency.

Elimination of high frequency disturbances concerned with inducing the common mode voltage in load phase supplied by matrix converter proves to be an essential issue. The monograph presents mathematical analysis of three control strategies that entirely eliminate common mode voltage. Two of the strategies are original achievements of the author, published in 2005 for first time.

Elimination of the common mode voltage is realized also in dual matrix converter, controlled with the use of the control method analysed in monograph. Dual matrix converter allows obtaining the value of voltage transfer ratio equal to one or even 1.5. Two out of four tested control methods, characterized by voltage transfer ratio equal to one, are original solutions devised by the author.

The monograph presents also the analysis of over modulation range of control applied to individual classical direct matrix converter. This issue has been taken into account for indirect and scalar control methods. The obtained results confirm that it is possible to achieve value of voltage transfer ratio equal to one.

Finally, capabilities of matrix converter to provide DC voltage at output terminals have been analysed. The monograph also contains the description of four-step commutation process and comparison of direct matrix converter with indirect matrix converter and indirect frequency changer.