Performance- Optimization of Matrix Converters Using Predictive Control and Wavelet Transform

V. Kandasamy¹, Sri Sathy Jairam ², N. K. Gauri Manohari³

¹Associate Professor, ²Assistant Professor, ³M.E Student, Kumaraguru College of Technology, Coimbatore, India.

Abstract— The matrix converter (MC) consists of an array of bidirectional switches, which facilitate the connection of supply to load directly without the usage of any intermediate storage elements or links. Matrix converter is very simple in structure and has powerful controllability. It has a superior performance compared to a conventional converter in terms of voltage transfer ration capacity, four quadrant operation, unity input power factor, non-requrement of DC capacitor and operation as pure sine waveforms with only high order harmonics in both line and load side. Secondly, the Predictive control method used in this proposed system can provide the able solution for the commutation problems associated with the control algorithm of a basic single stage conversion based matrix converter topology. Also a novel approach of using Wavelet transform can reduce the disadvantages caused by the remnant higher order harmonics. Thus overall performance of the proposed matrix converter is optimised by using proper harmonic mitigation technique using simple wavelet transform algorithm. Theoretical analyses and simulation results are provided to verify its feasibility.

Keywords— Matrix converter, Conventional converters, Predictive control, Harmonics, Wavelet Transform.

I. INTRODUCTION

The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters. It provides sinusoidal input and output waveforms, with sparingly low higher order harmonics and no subharmonics; it has inherent bi-directional energy flow capability; and enables eminent control of power factor. Another significant feature is that it has reduced number of energy storage elements, thus the usage of bulky and efficiency degrading elements can be avoided [2].

But the matrix converter includes within itself a few demerits. It limits the input-output voltage transfer ratio to approximately 87% for sinusoidal input and output waveforms. The need for semiconductor devices is more in this case when compared to the traditional direct AC-AC power frequency converters. This is due to the fact that, monolithic bidirectional switches are not used and therefore unidirectional devices, with various arrangements, have to be used for each bi-directional switch.

Finally, it is particularly sensitive to the disturbances of the input voltage system [2],[3]. Huge and restricted lifetime energy storage element. Because of the major advantages such as capability of regeneration, high quality sinusoidal input and output waveforms and adaptable power factor [1], matrix converter has been one among the AC – AC topologies that receive widespread attention for being a substitute for the ancient AC-DC-AC converters in the variable voltage and variable frequency AC drive applications.

The main objective of this paper is to provide predictive control algorithm for matrix converter specifically using predictive current control of the direct Matrix converter. The simulation involves six major elements: the references, predictive control algorithm, AC supply, input filter, converter, and load models. The three-phase output current references are generated by sine wave sources using MATLAB), which are configured with the desired peak amplitude, frequency, and phase angle. The core of the predictive control algorithm is implemented in an embedded MATLAB Function.

Mathematical analysis tools are used for accurate study of the issue that occurs due to harmonics caused in the output end in electrical signals like voltage or current signals of the proposed system. The most traditionally used approach is the Fourier Transform. The Fourier Transform enables extraction of frequency contents of recorded signals. But this tool cannot be applied for short-term transients like impulses and oscillatory transients in a power system [5].

The Short Time Discrete Fourier Transform was then used, cannot track the signal dynamics properly for non-stationary signals due to the limitations of fixed window width. Therefore, to study even the transient signals, a new analysis tool – “Wavelet Transform” can be used. Wavelet transform uses short windows at high frequencies and long windows at low frequencies; thus closely monitoring the characteristics of non-stationary signals. These characteristics of the wavelet transform provide an automated detection, localization, and classification of power quality disturbance waveforms.
II. SINGLE STAGE POWER CONVERSION

Traditional power converters perform the ac/ac power conversion by converting ac to dc through a rectifier, and then converting dc back to ac via an inverter. An alternative to these conventional indirect power converters is the direct power converter which is known as Matrix converter, as shown in Figure 2.1. The matrix converter is a Forced Commutated Cyclo-converter (FCC) which uses an array of controlled bidirectional switches as the main power element to create a variable output voltage system with unrestricted frequency [2].

![Fig.2.1 Single stage power conversion using matrix converter.](image1)

The key element in a matrix converter is the fully controlled four-quadrant bidirectional switch, which allows high-frequency operation [4]. The matrix converter has no limit on output frequency due to the fact that it uses semiconductor switches with controlled turn-off capability like IGBT, MOSFET, and MCT.

![Fig.2.2 Switch Arrangement of Matrix Converter](image2)

III. PREDICTIVE CONTROL ALGORITHM FOR MATRIX CONVERTER

Predictive current control model using Simulink as shown in Fig.3.1 is formulated by following a set of descriptive algorithms. The core of the predictive control algorithm is implemented in an embedded MATLAB function whose inputs are the grid voltages and currents, capacitor voltages, measured load currents, and reference load currents. The reference of the instantaneous reactive power is set to zero in order to have zero instantaneous reactive power on the input side of the system. The block outputs are the gating signals to be applied to the direct Matrix converter.

The AC-supply is generated by sine wave sources, which are configured with the desired peak amplitude, frequency, and phase angle. An LfCf filter is required at the input of the converter to reduce the high-frequency current harmonics caused by the switching operation and the inductive nature of the AC-line.

![Fig.3.1 Simulink model for Predictive current control of Matrix converter.](image3)

IV. WAVELET TRANSFORM FOR HARMONIC ANALYSIS

Wavelets are functions that wave above below the x-axis [7]. They have the following features: 1. Varying frequency, 2. limited duration, 3. Average value of zero. The basic function of wavelet transforms is given as below.

\[ f(t) = \sum_k a_k \psi_k(t) \]

The basis function can be subjected to translations and scaling based on the following Dyadic Grid:

\[ \psi(s, t, t) = \frac{1}{\sqrt{2^j}} \psi \left( \frac{t-k2^j}{2^j} \right) = \psi_k(t) \]
A. Discrete wavelet transform:

Discrete Wavelet transform enables MULTI RESOLUTION ANALYSIS by which different frequencies are analysed with different resolutions. The mother wave is decomposed into different sub bands of frequencies using successive high pass and low pass filters. Instantaneous low frequency component- cAj & instantaneous high frequency component- cDj. THD is determined by summing all harmonic components in the multi-sub band [6],[9].

\[ THD = \sqrt{\sum_{j} c_{Dj}^2 + \sum_{j} c_{Aj}^2} \]

B. Multi Resolution Analysis:

The Mallat algorithm is used in wavelet transforms to apply multi resolution analysis of transient signals[8]. The output of the wind energy conversion system is analysed using this algorithm, to say more specifically, discrete wavelet analysis is performed. Using successive lowpass & highpass filters a signal is decomposed into High frequency (cD) and low frequency (cA) samples.

\[ s = \sin(20.*\text{linspace}(0,\pi,1000))+0.5.*\text{rand}(1,1000); \]
\[ [cA,cD] = \text{dwt}(s,'db2'); \]
\[ \text{stem}(cA) \]
\[ \text{stem}(cD) \]

V. SIMULATION RESULTS

The simulation results of the Predictive current control of matrix converter and the results of the harmonic analysis are put forth in this section. The predictive current control involves the following simulation parameters
1. Start time 0.0 [s]
2. Stop time 0.15 [s]
3. Solver type fixed step
4. Solver ode 5
5. Fixed-step size 1e-6 [s]

The simulation of Wavelet Transforms is done using MATLAB tool box pertaining functions related to synthesis, analysis and study of Wavelets especially with specified reference to Discrete wavelet transform. The Basic code for Discrete Wavelet transform that can be used for spectral analysis and harmonic analysis is as given as follows

\[ s = \sin(20.*\text{linspace}(0,\pi,1000))+0.5.*\text{rand}(1,1000); \]
\[ [cA,cD] = \text{dwt}(s,'db2'); \]
\[ \text{stem}(cA) \]
\[ \text{stem}(cD) \]
VI. CONCLUSION

Streamlining in terms of performance of the Matrix converter is achieved; as pure sinusoidal output voltage and output current are obtained. Matrix converter is more efficient than the conventional AC-DC-AC converter topologies and the proposed system has higher efficiency and reliability. The Wavelet transform approach enables the process of performance optimisation even more. This system can also be extended and used for classification of power quality problems; as in this case - The Total Harmonic Distortion. The result of evident mitigation of harmonic distortion is charted.

REFERENCES


V. Kandasamy received B.E degree in Electrical and Electronics Engineering from Bharathiar University, Coimbatore, India in 1998, the M.E degree in VLSI Design from SASTRA University, Thanjavur, India in 2003, pursuing Ph.D. degree from Anna University, India. He is currently working as an Associate Professor at Kumaraguru College of Technology, Coimbatore, India. His current research Wind Energy Power Converters, FPGA based system Design.

Sri Sathya Jairam received her B.E degree in Electrical and Electronics Engineering from PSNA College of Technology, Dindugal, India in 2003 and M.E Power Systems (EEE) degree in B.S.Abdur Rahman Crescent Engineering College, Chennai, India in 2009. Currently she is working as Assistant Professor in Kumaraguru College of Technology, Coimbatore, India.

Gauri Manohari, N. K received her B.E degree in Electrical and Electronics Engineering from Sri Ramakrishna Engineering College, Coimbatore, India, in 2011 and is currently doing her M.E degree in Power Electronics and Drives at Kumaraguru College of Technology, Coimbatore, India.