ELK331E-HW2

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30 December 2024

1 Three Phase Matrix Converter

Matrix converters are advanced power electronic devices that enable direct conversion of AC power from one frequency and voltage level to another, without the need for an intermediate DC link. Unlike traditional converters that rely on rectification and inversion stages, matrix converters utilize a matrix of bidirectional switches to achieve this functionality. This approach offers several advantages, such as compact design, reduced energy storage requirements, and bidirectional power flow capability.

The core operating principle of a matrix converter involves synthesizing the desired output voltages by appropriately switching the input voltage phases. This is typically achieved using sophisticated modulation techniques, the most prominent being Space Vector Modulation (SVM). SVM optimizes the switching sequences to maximize the output voltage quality while minimizing harmonic distortion and switching losses.

2 Finding R and L Values

The resistive and inductive values of the load, denoted as R and L, are calculated to meet the specified power and power factor requirements. The problem states that the load should have an apparent power of $S = 20kVA$, a power factor of $\cos\phi = 0.8$, and is supplied by a 3-phase grid with a line-to-line voltage of $400V RMS$ at $50Hz$.

Step-by-Step Calculation 1. Calculate Real Power (P):

$$P = S \times \cos\phi = 20kVA \times 0.8 = 16kW$$

2. Calculate Load Current (I_L):

$$I_L = \frac{S}{\sqrt{3} \cdot V_{LL}} = \frac{20,000}{\sqrt{3} \cdot 400} \approx 28.87 ARMS$$

3. Determine Impedance Magnitude ($|Z|$):

$$|Z| = \frac{V_{LL}}{\sqrt{3} \cdot I_L} = \frac{400}{\sqrt{3} \cdot 28.87} = 8\Omega$$

4. Find Resistance (R):

$$R = |Z| \cdot \cos\phi = 8 \cdot 0.8 = 6.4\Omega$$

5. Find Inductive Reactance (X_L):

$$X_L = \sqrt{|Z|^2 - R^2} = \sqrt{8^2 - 6.4^2} = \sqrt{64 - 40.96} = \sqrt{23.04} = 4.8\Omega$$

6. Calculate Inductance (L):

$$L = \frac{X_L}{2\pi f} = \frac{4.8}{2\pi \cdot 50} = \frac{4.8}{314.16} \approx 0.0153H \ (15.3mH)$$

Final Values - $R = 6.4\Omega$ - $L = 15.3mH$

These values satisfy the requirements for power and power factor, ensuring proper operation of the load under the specified conditions.
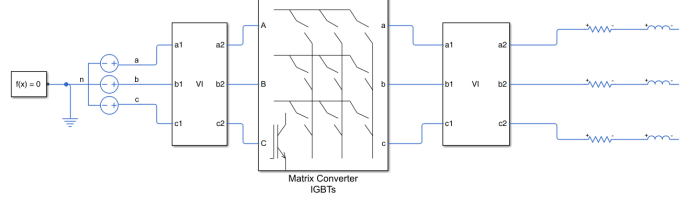

Figure 1: Circuit Diagram of the Three Phase Matrix Converter

3 Space Vector Modulation (SVM)

Space Vector Modulation is a powerful technique for controlling matrix converters. It represents the three-phase voltage system as a single rotating vector in the complex plane. This method allows for precise synthesis of output voltages and currents.

The SVM process involves: 1. Sector Identification: The space vector plane is divided into six sectors. The position of the reference voltage vector determines the active sector. 2. Vector Decomposition: The reference vector is decomposed into a combination of two adjacent active vectors and one zero vector. 3. Timing Calculation: The durations for which each vector is applied are calculated based on the desired output voltage and switching period. 4. Switching Sequence: The calculated vectors are applied in a specific order to minimize switching losses and ensure smooth voltage transitions.

SVM enhances the performance of matrix converters by: - Achieving better voltage utilization. - Minimizing harmonic distortion. - Allowing flexible control of output voltage amplitude, frequency, and phase.

4 IGBTs in Matrix Converters

Insulated Gate Bipolar Transistors (IGBTs) are the core switching devices used in matrix converters. IGBTs combine the high input impedance and fast switching characteristics of a MOSFET with the high current and low conduction losses of a bipolar transistor. This makes them ideal for high-power applications like matrix converters.

Connection of IGBTs In a three-phase matrix converter, nine IGBT switching blocks are utilized to form a 3x3 matrix. Each switching block comprises an IGBT and a diode connected in antiparallel to allow bidirectional current flow.

This configuration enables the converter to switch between any input phase to any output phase, providing flexible control over the output voltage and current.

The switching strategy is governed by modulation techniques such as Space Vector Modulation, which ensures proper timing and sequence of the IGBT switches to achieve the desired output waveform while minimizing losses and harmonics.
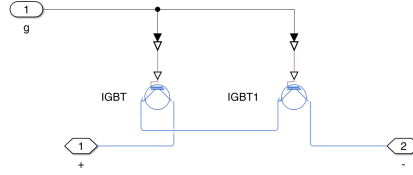

Figure 2: Switching Block in Matrix Converter (One of Nine Blocks)

5 Current Modulation and Voltage Modulation Blocks

Current modulation and voltage modulation blocks are critical in ensuring the proper operation of the matrix converter. These blocks help achieve the following:

- Current Modulation: - Maintains sinusoidal input current waveforms. - Ensures proper synchronization with the grid voltage, which is essential for minimizing harmonic distortion and improving power quality.

- Voltage Modulation: - Synthesizes the desired output voltages based on the reference signals. - Controls the amplitude, frequency, and phase of the output voltage to meet load requirements.

Both modulation blocks are integral to the implementation of Space Vector Modulation. They work together to ensure the converter operates efficiently, with minimal losses and optimal waveform quality.

SVM and Matrix Converter Switching The matrix converter switching strategy is dictated by the SVM algorithm, which optimizes the timing and sequence of the nine IGBT switching blocks. This ensures: - Accurate synthesis of the desired output voltage vector. - Minimal switching losses by reducing the frequency of switch transitions. - High-quality output waveforms with low harmonic distortion.

The diagram in Figure 3 showcases the organization of the switching and modulation blocks, highlighting the combinational circuits used in implementing the SVM algorithm. These subsystems are modeled in MATLAB/Simulink, adapted from three-phase converter and SVM examples, demonstrating their practical relevance and applicability.
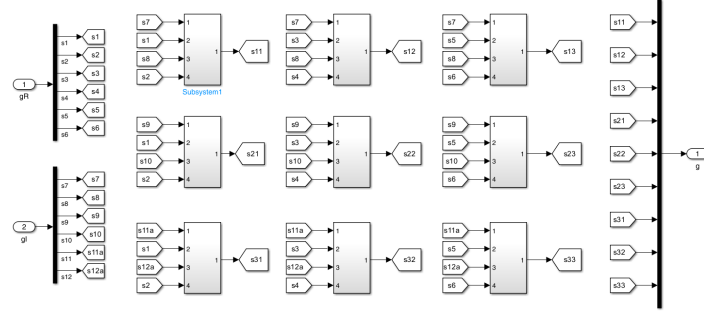
Figure 3: Subsystem Diagram of Switching and Modulation Blocks in Matrix Converter

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