Selective Harmonics Elimination for Five Level Inverters with Unequal DC Sources

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Abstract- *The present paper is related to "Selective Harmonics Elimination for five Level Inverters with Unequal DC Sources". The main aim of the project is the usage of couple of multilevel inverters (MLI), dc sources are enable to do functioning at higher levels of voltages and switching frequencies of lesser values as compared to the normally available inverters. A technique called "Selective Harmonic Elimination (SHE)" is used in this paper at 1st order (fundamental frequency) to remove the harmonics and improve the efficiency. A modulation procedure related to a method of harmonic removal is established in case of 5-level inverters with uneven values of voltage at dc link. The methodology provides the result in analytical form. Calculations of switching angles and how they affect harmonic distortion has been observed which is similar to the simulation.*

Index Terms*— Inverter, harmonics, Modulation Technique****.***

I. INTRODUCTION

In determination of the usage of multilevel inverters (MLI), DC sources, would be proficient to function at upper levels of voltage and at lesser values of switching frequencies independently as compared to conventional type of inverters. In similar fashion, to get synchronization in staircase voltage waveforms at output that ensures better reduced value of harmonic content and also electro-magnetic interferences (EMI). For this purpose, now-a-days, they're deliberated as a very attractive answer for high/medium value of voltage power usage [1]. For eliminating losses and improving efficiency of converter the technique which would be used are "Very Low Frequency Modulation" techniques, like "Selective harmonic elimination (SHE)".

In paper [2] theory of "symmetric polynomials" is explained. With the increase in levels, the degree of relative polynomials also becomes high; therefore, the SHE technique is complicated technique. To get the solution of non-linear equations that explain the problem some iterative techniques can be used like "Newton-Raphson method", but the difficulty is requirement of an appropriate initial guess. "Heuristic algorithms", like "genetic algorithm (GA) and "particle swarm optimization (PSO)" are very exciting in case of unavailability of analytic solution, therefore these can provide the nearby solution giving a smooth set of data [3].Though, and they account a disadvantage of computationally severe and formed expressions are complex. In paper [4] an inverter having five-level is projected to the "Bee algorithm (BA)" to solve the expressions and the get the supremacy.

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II. SWITCHING ANGLE CALCULATION USING ANALYTICAL PROCEDURE

Two angles of switching i.e. α1 and α2 (0 < α1 < α2 <π) of inverter removes harmonics from the waveform of output voltage. From figure 1 one can see a Five-level inverter in cascaded form supplied by 2 different and uneven dc type sources represented by V1 and V2.

$$u_1 \cos(k\alpha_1) + u_2 \cos(k\alpha_2) = 0$$

$$u_1 \cos(\alpha_1) + u_2 \cos(\alpha_2) - m_1 = 0 \ldots\ldots(1)$$

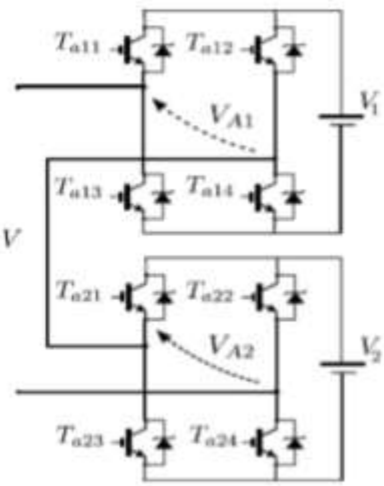

Fig.1: Single-phase cascaded H-Bridge five level inverter with unequal dc sources.

Wherein, value of k = 03, 05, 07, and
m1 denotes modulation index.

a) By Eliminating 3rd Harmonics **:**

By introducing Chebyshev polynomials:

$$T_1(x_i) = x_i = \cos(\alpha_1) \quad (2)$$

$$\text{And } T_3(xi) = 4xi^3 - 3x_i = \cos(3\alpha_1) \quad (3)$$

I = 1,2 by transforming polynomial system

$$\begin{cases} v_1 T_3(x_1) + v_2 T_3(x_2) = 0 \\ v_1 T_1(x_1) + v_2 T_1(x_2) - m_1 = 0. \end{cases} \quad (4)$$

The following final system can be obtained:

$$a_3 x^3_1 + a_2 x^2_1 + a_1 x_1 + a_0 = 0$$

$$x_2 = -b_1 x_1 + b_0 \quad (5)$$

2 condition that has to be satisfied are given by :

- "Each component of the solution should belong to the interval [0, 1]",and

- "x1>x2".

The expression 5 has 3 solution but only one will be considered as that has to satisfy the above given conditions.

The angles of switching are calculated by:

a1= arccos (x1), and a2 = arecos (x2)

The curve is shown in Figure 2 for a value of k =3. To show 2 different functions on a single graph a continuous line and dashed line has been used.

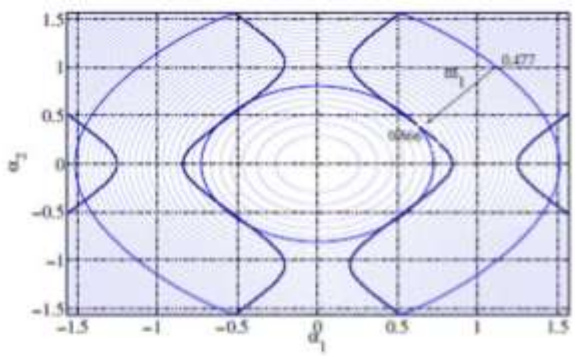

Fig. 2: Curves in implicit form of the system (1) for *k* = 3.

b) By Eliminating 5th Harmonics:

By considering the term,

$T_5(x_i) = 16x^5 i - 20x^3 i + 5xi = \cos(5\alpha_1)$ i = 1; 2, in addition to T1 (xi) and T3 (xi), the following polynomial system can be obtained:

$$v_1T_5(x_1) + v_2T_5(x_2) = 0$$

$$v_1T_1(x_1) + v_2T_1(x_2) - m1 = 0 \quad (6)$$

Algebraic manipulations lead to the following system:

$$c_5x^5{}_1 + c_4x^4{}_1 + c_3x^3{}_1 + c_2x^2{}_1 + c_1x_1 + c_0 = 0$$

$$x_2 = - b_1x_1 + b_0 \quad (7)$$

Where, $c_5 = 16v_1(1-b_1^4)$, $c_4 = 80m_1b_1^4$, $c_3 = 20v_1[b_1^2(1-8b^2_0) -1]$, $c_2 = 20m_1b^2{}_1(8b^2_0 - 3)$, $c_1 = 20m_1b_0b_1(3 - 4b^2_0)$, $c_0 = m_1[5 + 4b^2_0(4b^2_0 - 5)]$. Among the five solutions of the system (7) in C2 two at most valid. Figure 3 shows, for k = 5,

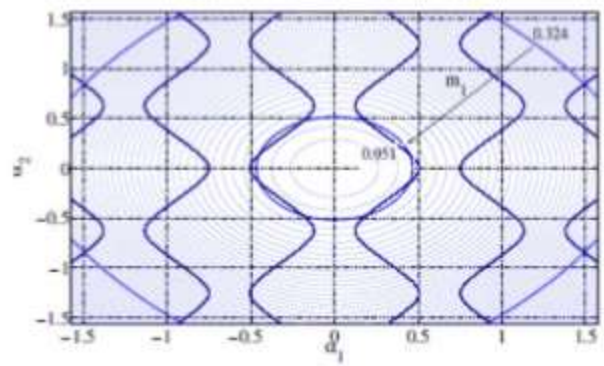

Fig. 3: Curves in implicit form of the system (1) for $k = 5$.

APPLICATION

Two different cases are taken for a 5-level inverter with cascaded connection characterized by values v2 = 0:45 and v1 = 0:55 are deliberated:

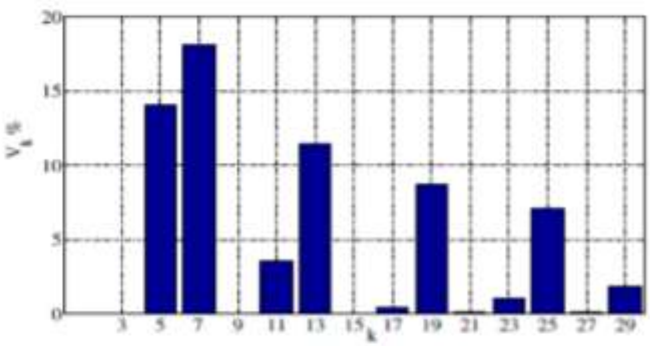

Fig. 4: Vk % obtained eliminating the third harmonic for $m1 = 0.5$ and $\alpha 1 = 0.49465$ rad, $\alpha 2 = 1.53540$ rad.

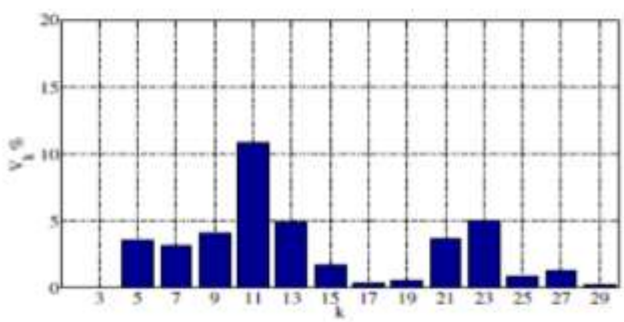

Fig. 5: Vk % obtained eliminating the third harmonic for $m1 = 0.83$ for $\alpha 1 = 0.28436$ rad, $\alpha 2 = 0.83483$ rad.

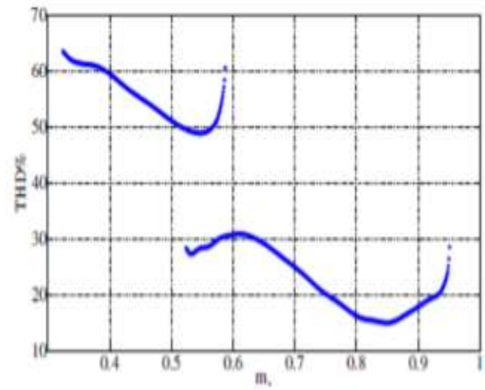

Fig. 8: THD% obtained eliminating the fifth harmonic.

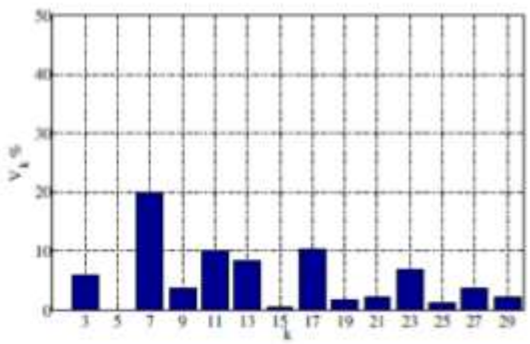

Fig. 9: % obtained eliminating the fifth harmonic for $m1 = 0.55$, $\alpha1 = 0.38753$ rad, $\alpha2 = 1.48004$ rad

Solution encounters in the interval of [0; 1] however modulation index includes 2 intervals for the elimination of 3rd harmonics while taking the cases of unbalanced situation. In case the value of v2 amplifies it become lesser. For this, the 1st interval transfers to the left side. In case of 5th harmonic removal, unbalancing condition, modulation index's 3 intervals exist in [0; 1], whereas only 1 or 2 solutions exist. While increasing the values of v2 these intervals decrease.

From Figure it can be seen that value of modulation index values changes between 0:35 and 0:5, Due to unbalancing condition better results of THD values are obtained.

III. CONCLUSION

The project that uses a "Modulation Technique" according to the "Selective harmonic elimination method" is projected to multi-level converters with uneven value of dc link voltages has executed properly. The solution in the analytical form equivalent to mathematical model of non-linear expression has been found, the values of THD% and switching angles are observed. The conditions v1 < v2 and v2 < v1 shows the unbalancing and have been deliberated for either 3rd or alteration between v2 and v1 upsurges.

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