

A Novel Hybrid Multi Level Inverter with Reduced Number of Switches Using Equal Area Criteria with Comparison of PWM Switching Technique

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ABSTRACT: In this paper, a novel multi level inverter (MLI) with reduction of switches using Pulse Width Modulation (PWM) and Equal Area Criteria (EAC) is proposed. We all know when the number of switches for required number of levels is more, the control circuit become complex and the overall efficiency will reduce. The required number of power switches for multi level inverter should be as less as possible. In this proposed MLI, 5-level with reduced number of switches is simulated with the help of MATLAB/Simulink software. We observed that the Total Harmonic Distortion (THD) is minimum in EAC than PWM technique. The simulation results of 5-level with both methods are shown.

KEYWORDS: Multi Level Inverter (MLI), Total Harmonic Distortion (THD), Pulse Width Modulation (PWM), Equal Area Criteria (EAC).

I. INTRODUCTION

Now a day the power electronic inverters are becoming popular for various home and industrial drive applications. In recent years, inverters have even become a necessity for many applications such as speed control of motors, power supply during emergency conditions like hospitals. Up to now we have many multi level inverter topologies but one of the most obvious disadvantages is the numerous of power switches required. Every switch requires a gate driver circuit, therefore increasing the complexity in control circuit and size of the overall circuit. The requirement of multiple gate driver circuit leads to large expense. So there is a need of reducing the number of switches in MLI. In this proposed topology with minimum number of switches the required multiple levels can get with reduction of THD [1]. As we know with less number of devices the overall efficiency will increase, the size and cost also reduces.

II. PROPOSED TOPOLOGY

The proposed topology has a set of series and parallel combination of power switches and sources as shown in fig. 1. The switches SM1 and SM4 will conduct at different instants to prevent the short circuit of sources. The switches which are connected in series will conduct according to switching table. The series combination of switches with asymmetrical sources will generate the required number of levels as rectified output. To get both +ve and -ve wave form one more H-bridge were used [2].

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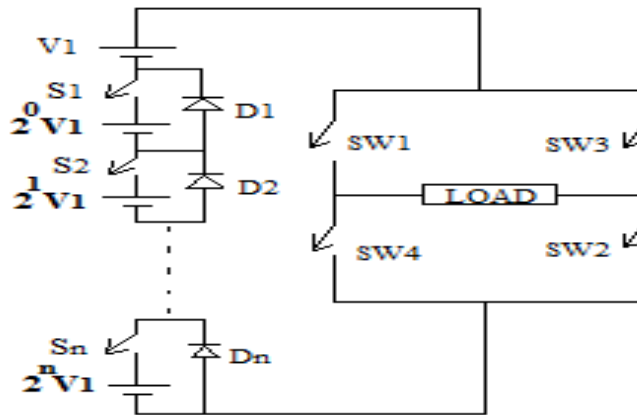


Fig.1 Proposed Hybrid Multi Level Inverter

The voltage ratios for N number of levels is given as

$$V_1 : 2^0 V_1 : 2^1 V_1 : \dots : 2^n V_1$$

The voltage ratios for basic 5-level inverter is shown below

$$V_1 : 2^0 V_1$$

In symmetrical DC sources, with more power sources and more steps in output wave form. A more sinusoidal wave inverter will power devices and loads with more accuracy, leading to less power losses. But for same number of levels as in symmetrical sources that can get by asymmetrical sources with reduction of switches and improved efficiency of the inverter. As we know when the number of devices is less, the reliability of the system also increases. The basic 5-level inverter circuit as shown

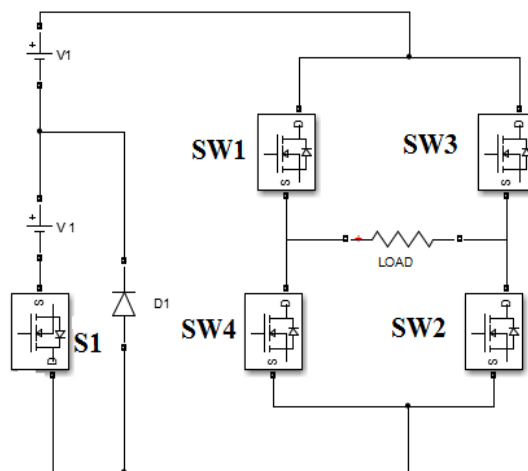


Fig. 2 Basic 5-level MLI in proposed topology

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TABLE 1

S.No	S1	SW1	SW2	SW3	SW4	Output voltage
1	ON	ON	ON	OFF	OFF	2V ₁
2	OFF	ON	ON	OFF	OFF	1V ₁
3	OFF	OFF	ON	OFF	ON	0V ₁
4	OFF	OFF	OFF	ON	ON	-1V ₁
5	ON	OFF	OFF	ON	ON	-2V ₁

The Switching Sequence of 5-Level MLI is show in table 1. The voltage which is connected directly to the H-bridge is the minimum voltage called step voltage in N-level MLI. This step voltage increases two levels in conventional hybrid MLI without increasing number of switches. The H-bridge switches control the step voltage in proposed MLI. Hence, increasing number of steps will increases the smoothness in output wave, thus the THD reduces.

III. SWITCHING TECHNIQUE

Up to now we have so many switching techniques but to reduce the effect of lower order harmonics on fundamental wave the best technique is Selective Harmonic Elimination (SHE) [3]. To find switching angles by iterative manner or by program can get. But the difficulty in iterative approach is solving Nth order non-linear equation is challenging task. To overcome this difficulty Newton-Rapson (NR) used for calculating angles. Again in this program we need initial angles. Finally, to overcome the above two difficulties we are using Genetic Algorithm (GA) [4], [5]. Here, the drawback is the length of the program and iterations required is more. There is need for going alternative method for calculating good switching angles. In this paper we implemented the simple technique called EAC [6]. We can calculate the effective switching angles by equating the areas shown in fig. 3. In this proposed topology the EAC switching technique is introduced and implemented. By comparing fundamental sine wave with stepped wave the switching angles can calculate.

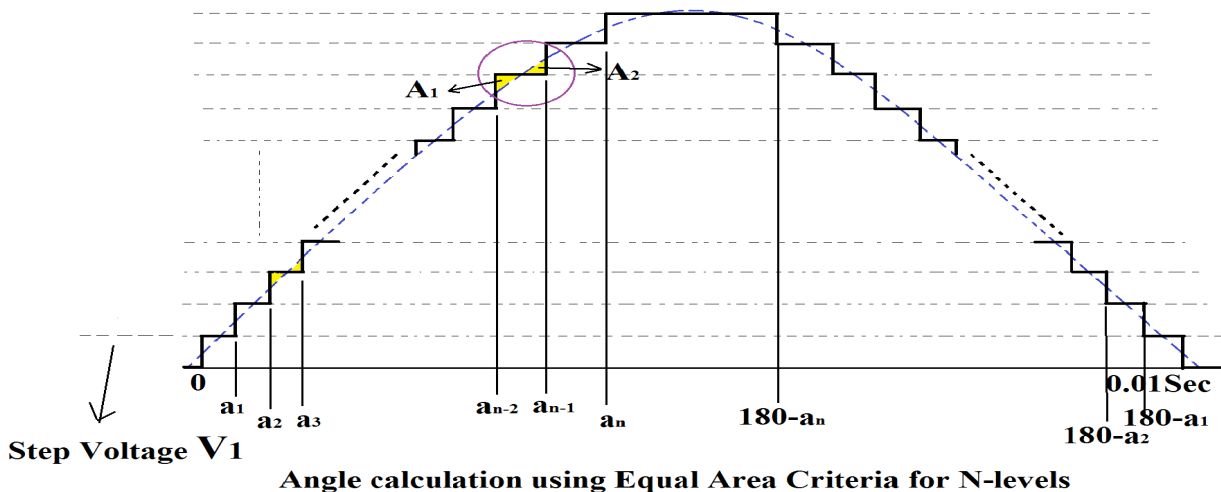


Fig. 3 Equal Area Criteria switching technique

Here, A₁ and A₂ are the areas shown in color. The stepped wave form constructed with the help of sinusoidal fundamental wave. Here the frequency of sine wave is 50Hz. To get minimum THD the areas of A₁ and A₂ should be equal. Hence the effect of lower order harmonics on fundamental wave can reduce. Here, a₁, a₂, - - - a_n are switching angles for n-levels and it should be <90°.

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Number of switching angles for N-levels = [(Number of levels-1)/2]

Mathematical formula for angle calculation:

$$N^{\text{th}} \text{ switching angle } \alpha_n \text{ (deg.)} = \left[\left[\text{Time at which the } N^{\text{th}} \text{ level vertical line touches the time axis (x-axis)} \right] * [2 * \text{fundamental frequency}] \right] * 180^{\circ}$$

By using above mathematical formula for N-number of levels the switching angles we can calculate.

The switching angles for 5 –level inverter shown below

$$\alpha_1 = 11^{\circ}, \alpha_2 = 36^{\circ}$$

These switching angles are given to H-bridge and S1 switches respectively. When SW1, SW2 are turned ON which gives $+V_1$ and for $+2V_1$ the switches S1, SW1 and SW2 should ON. PWM switching technique is also implemented for comparing with EAC. In this topology we are using H-bridge switches in two ways, mainly for polarity generating purpose and also to control the step voltage which is connected in series to the H-bridge.

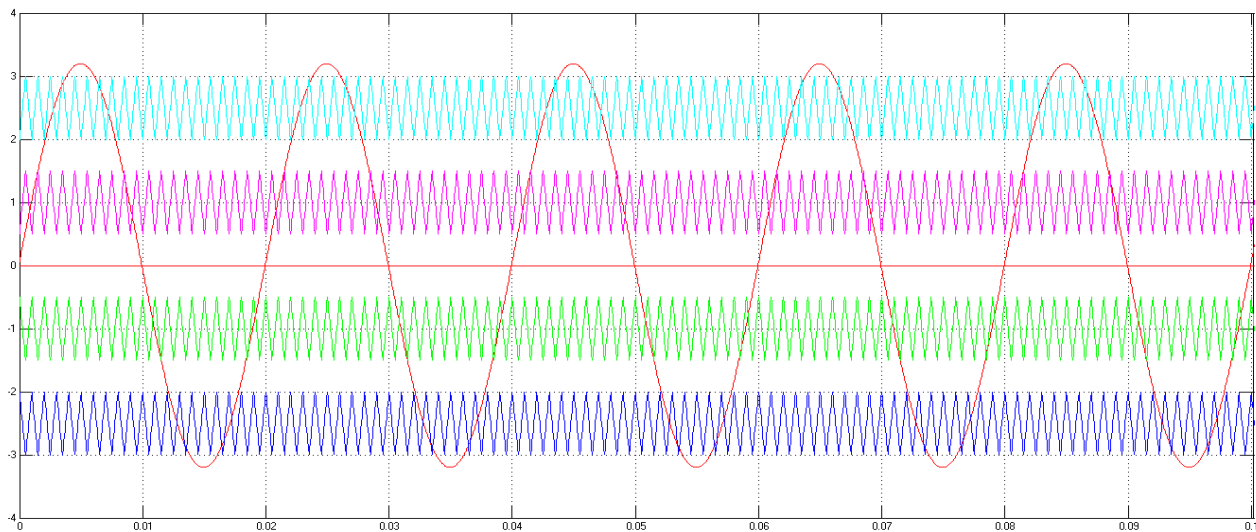


Fig. 4 Simulation Output of Pulses from POD –PWM Method

IV. SIMULATION RESULTS

The simulation model of proposed 5-level MLI is as shown in fig.5

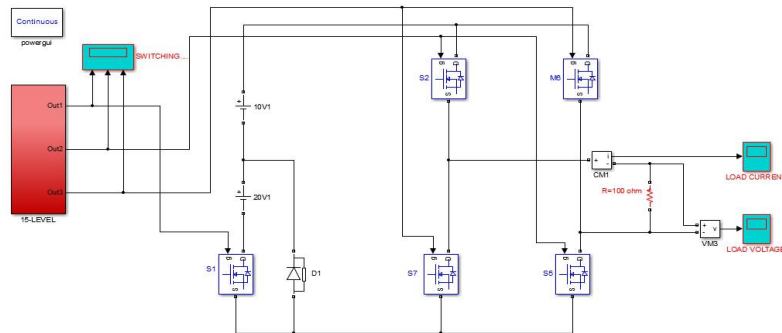


Fig. 5 Simulation circuit of proposed 5-level MLI

The simulation was done with resistive load by using both the techniques EAC and PWM in MATLAB/Simulink software. The simulation results are shown below

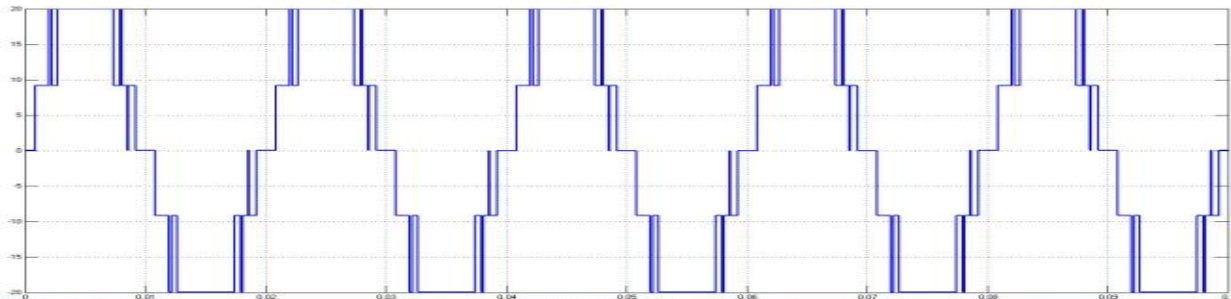


Fig. 6 Output voltage of 5 - level MLI with PWM (X-1msec, Y-10V/div.)

The output voltage waveform across R-load is observed and is shown in fig. 6. By comparing reference sine wave of 50Hz frequency with carrier wave of 1000Hz frequency to generate the switching sequence mentioned in table 1.

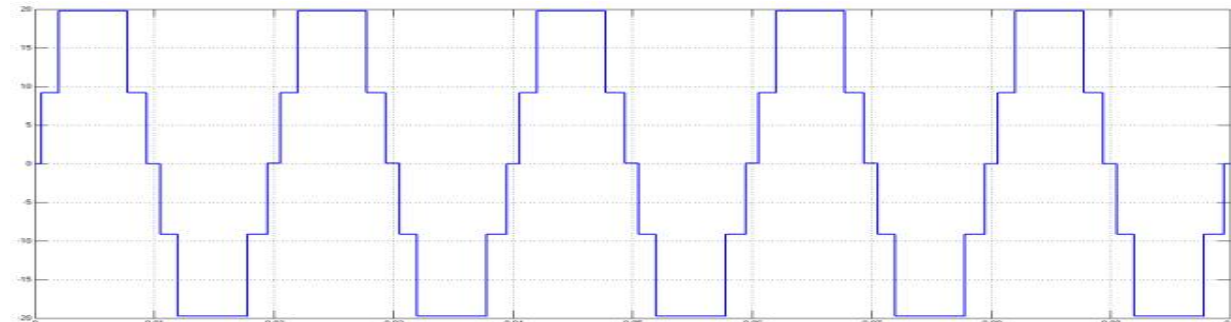


Fig. 7 Output voltage of 5-level MLI with EAC (X-1msec, Y-10V/div.)

By using the EAC switching technique for calculating best switching angles for 5-levels. After calculations, the simulation carried out with the help of pulse generators to turn ON the switches at that instant. The voltage wave with 5

steps is show in fig. 7.

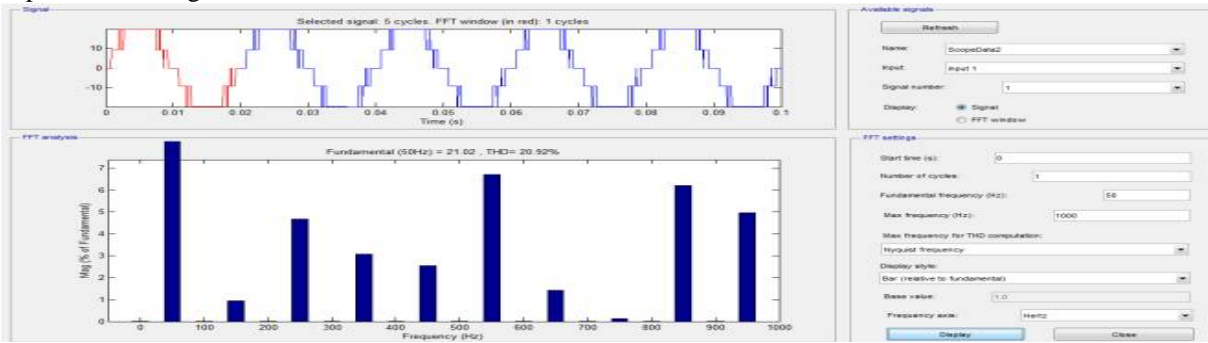


Fig. 8 FFT analyzer using PWM technique

The THD is 20.92% with PWM technique for 5-level MLI is shown in fig. 8.

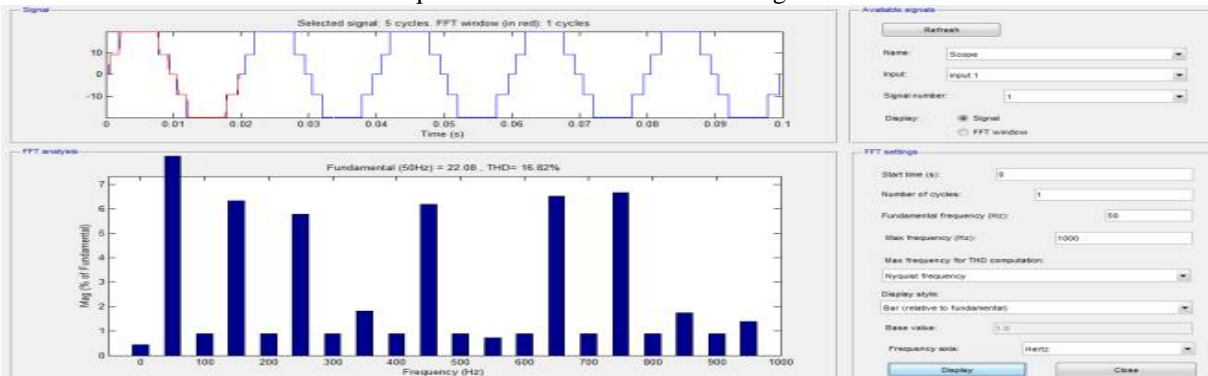


Fig. 9 FFT analyzer using EAC technique

The THD is 16.82% with EAC technique 5-levels is shown in fig. 9. The harmonic distortion is less in case of EAC but it is more in PWM technique [7]. The comparison of THD between two techniques is shown in fig. 10.

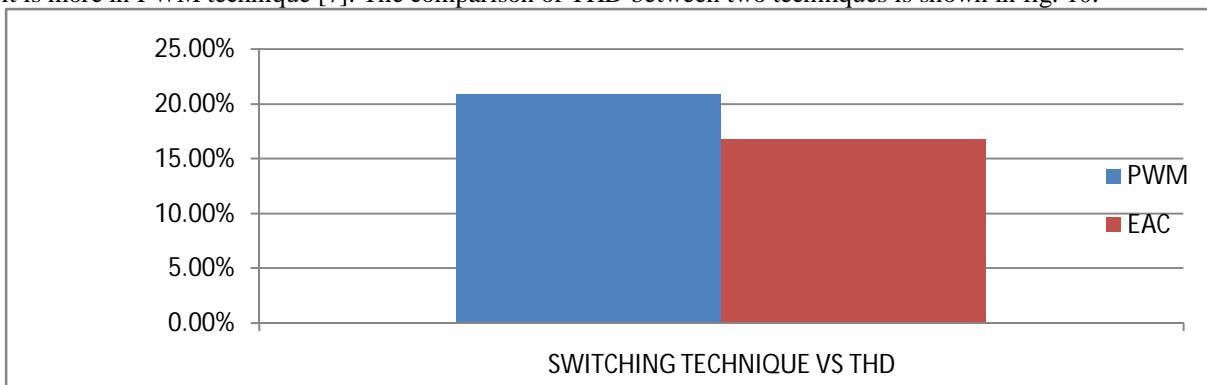


Fig. 10 Comparison of THD for 5-level MLI

From the above graph, it is clear that there is a much reduction in THD with EAC compared to PWM technique [8].

V. CONCLUSION

In this proposed topology the number of levels gets increased with reduction of number of power switches and also the THD is reduced by 19.6% in EAC compared to PWM technique for 5-level with resistive load. It is difficult to



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implement the PWM technique when more levels required in Hybrid MLI. With this proposed technique, no need of solving non-linear equations and without writing MATLAB program can find switching angles.

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