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Comparison of Hybrid Multi Level Inverter Topologies using Equal Area Criteria

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ABSTRACT: In this paper, a Hybrid multilevel inverters (MLI) are compared with minimum number of switches to reduce Total Harmonic Distortion (THD) by using equal area criteria (EAC) for 9 and 17-level are analyzed and simulation is carried out with a resistive load using MATLAB/Simulink.

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

I. INTRODUCTION

So far many MLI topologies are introduced for the reduction of Harmonics. In Hybrid MLI with six switches we can obtained only seven levels, and conventional cascaded type H-bridge inverter with asymmetrical sources to obtain 9-level it requires eight switches and also the THD is high [1]. When the number of switches increases the efficiency of the inverter reduces. Even though many switching techniques are available [2] the best way to reduce the fundamental lower order harmonics is selective harmonic elimination (SHE). In this paper, we are introducing a new MLI topology for achieving IEEE standard THD without increasing the switches for 9 and 17-levels.Using this technique there are two ways to calculate the switching angles [3]. One is mathematical approach, by solving non-linear equations by using iterative manner; while second approach is MATLAB programming based. In this we have two methods; Newton-Rapson (NR) [4] and Genetic Algorithm (GA) [5]. In NR method finding initial switching angles is a challenging task; while in GA there is no need to find initial angles, but the programming is complex and requires number of iterations. To overcome these difficulties, in this paper a simple switching technique called equal area criteria (EAC) is implemented and is a one of the lower order harmonic elimination technique.

II. PROPOSED TOPOLOGY

With asymmetrical voltage sources and combination of level generating and polarity generating cells the new MLI constructed. The proposed MLI is as shown below,

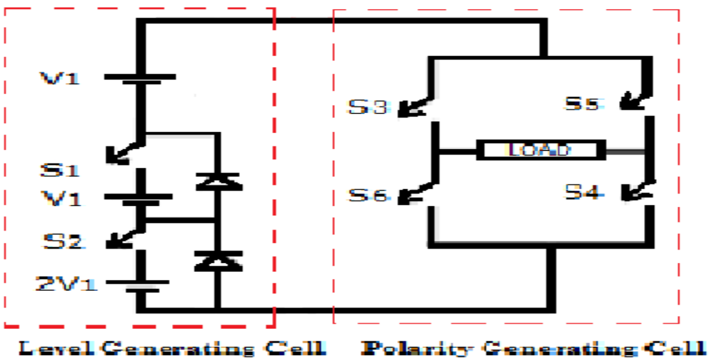

Fig. 1 Proposed 9-level MLI with asymmetrical sources

Here, the voltage V_1 is step voltage of minimum voltage and the voltage ratios of asymmetrical sources for 9 level and 17 level are respectively

$$V_1 : V_1 : 2V_1 \text{ and } V_1 : V_1 : 2V_1 : 4V_1$$

Here we have two cells, the LGC generates number of output levels with the help of switching sequence and PGC generates +ve and –ve half waves for AC operation. The voltage across LGC is seventeen level DC and the frequency of voltage wave is two times of output voltage frequency.

III. SWITCHING TECHNIQUE

Even though we have so many switching techniques among all, the best way to get minimum THD is SHE.
By solving non-linear equations is given below,

$$\begin{cases} \dfrac{4V_{dc}}{\pi}(\cos(\theta_1)-\cos(\theta_2)\ldots+\cos(\theta_N)) = V_F \\ \cos(5\theta_1)-\cos(5\theta_2)\ldots+\cos(5\theta_N)=0 \\ \cos(7\theta_1)-\cos(7\theta_2)\ldots+\cos(7\theta_N)=0 \\ \ldots\ldots. \\ \cos(m\theta_1)-\cos(m\theta_2)\ldots+\cos(m\theta_N)=0 \end{cases}$$

Finding angles by solving the above non-linear equations is possible if levels are less but in it is very difficult when levels are more and time consuming. These types of equations can be solve with the help of MATLAB program using any of the above programming based techniques. The simple technique EAC is implemented to find initial values and these initial switching angles will give minimum THD for any number of levels. The EAC is a one of the method to find best switching angles [6].
By this EAC method we can find the best switching angles for the switches, by dividing half of fundamental sine wave by horizontally and vertically with step voltage and time (ms) respectively.

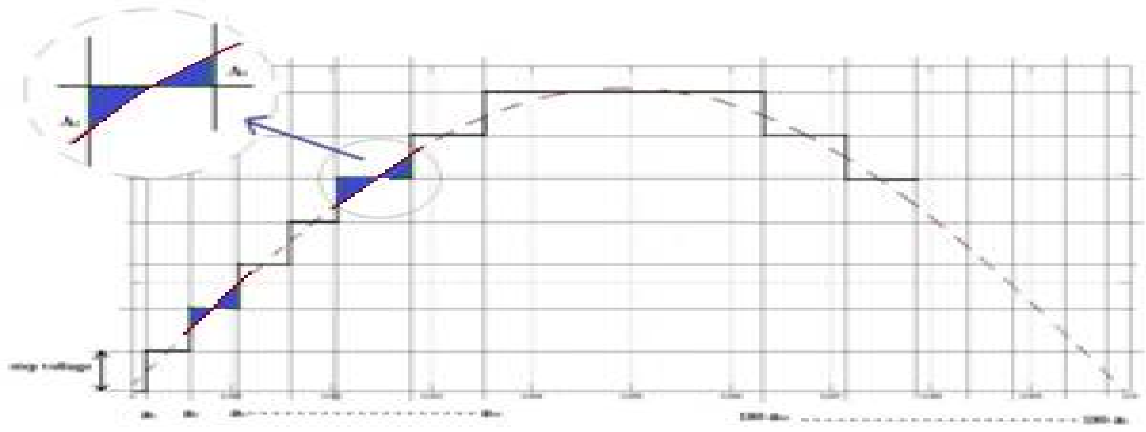

Fig. 2 Equal Area Criteria (EAC) switching technique

Here, A_1 and A_2 are the areas shown in above figure. To get minimum THD the areas of A_1 and A_2 should be equal. The fundamental switching frequency is taken as 50Hz. The step voltage is a minimum voltage that presented in level generation circuit (LGC).$a_1, a_2, a_3, \ldots a_n$ are the switching angles for N-level MLI. The angles should be $<90^0$.

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$0<a_1<a_2<a_3<a_4<a_5<a_6<a_7$ - - - - $a_n<90^0$
Mathematical formula for angle calculation:
N^{th} switching angle a_n (deg.) =
[[Time at which the N^{th} vertical line touches the time axis (x-axis)]$*$[$_{2*\text{fundamental frequency}}$]]$*180^0$
The switching angles for 9and 17-levels are given below,
$a_1=5^0$, $a_2=19^0$, $a_3=37^0$,$a_4=56^0$
$a_1=2^0$, $a_2=9^0$, $a_3=16^0$, $a_4=24^0$, $a_5=32^0$,$a_6=41^0$, $a_7=53^0$, $a_8=66^0$
The above switching angles the THD for 9 and17-levels are observed and compared [7].

TABLE-I Switching sequence for 9-level MLI

S.NO	S_1	S_2	S_3	S_4	S_5	S_6	Output voltage
1	1	1	1	1	0	0	$4V_1$
2	0	1	1	1	0	0	$3V_1$
3	1	0	1	1	0	0	$2V_1$
4	0	0	1	1	0	0	$1V_1$
5	0	0	0	0	0	0	$0V_1$
6	0	0	0	0	1	1	$-1V_1$
7	1	0	0	0	1	1	$-2V_1$
8	0	1	0	0	1	1	$-3V_1$
9	1	1	0	0	1	1	$-4V_1$

TABLE-II Switching sequence for 17-level MLI

S.NO	S_1	S_2	S_3	S_4	S_5	S_6	S_7	Output voltage
1	1	1	1	1	1	0	0	$8V_1$
2	0	1	1	1	1	0	0	$7V_1$
3	1	0	1	1	1	0	0	$6V_1$
4	0	0	1	1	1	0	0	$5V_1$
5	1	1	0	1	1	0	0	$4V_1$
6	0	1	0	1	1	0	0	$3V_1$
7	1	0	0	1	1	0	0	$2V_1$
8	0	0	0	1	1	0	0	$1V_1$
9	0	0	0	0	0	0	0	$0V_1$
10	0	0	0	0	0	1	1	$-1V_1$
11	1	0	0	0	0	1	1	$-2V_1$
12	0	1	0	0	0	1	1	$-3V_1$
13	1	1	0	0	0	1	1	$-4V_1$
14	0	0	1	0	0	1	1	$-5V_1$
15	1	0	1	0	0	1	1	$-6V_1$
16	0	1	1	0	0	1	1	$-7V_1$
17	1	1	1	0	0	1	1	$-8V_1$

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IV. SIMULATION RESULTS

Hybrid MLI simulation circuit with resistive load is as shown below

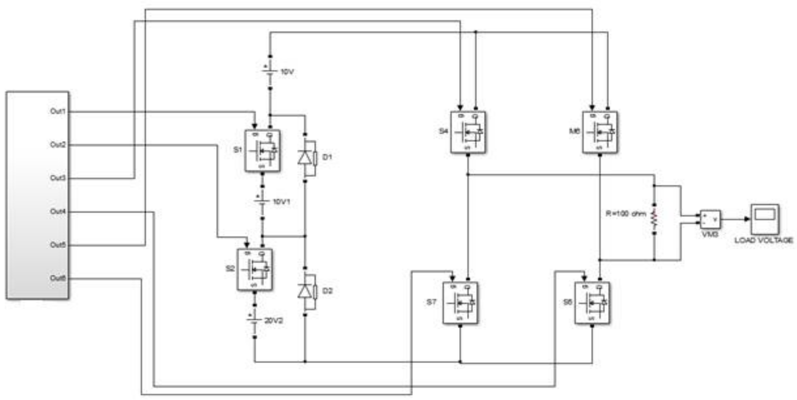

Fig. 3 Simulation circuit of proposed Hybrid 9- level inverter

After calculation of switching angles we used pulse generators for LGC and PGC to Switch ON and OFF the switches at calculated switching angles [8], [9].We achieved the THD within the IEEE standards for 17-level compared to 9-level.The simulation results of above levels are shown below

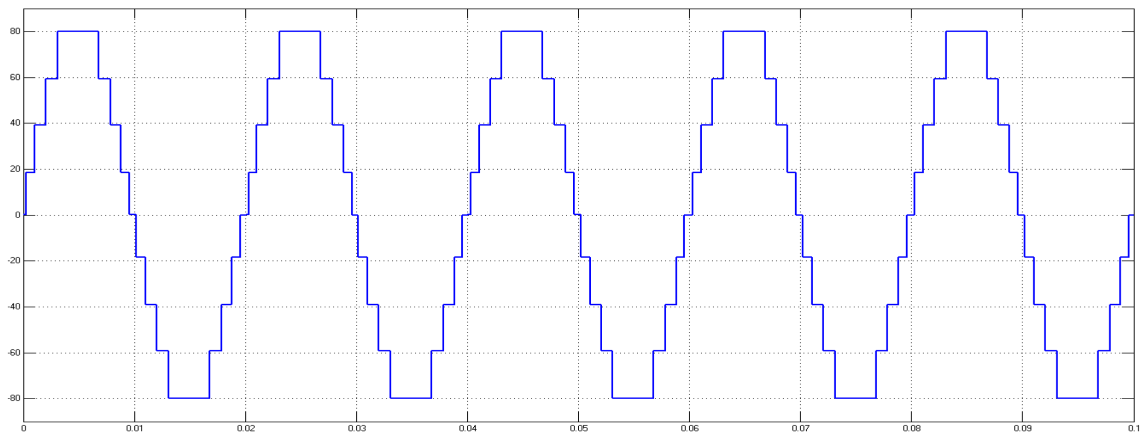

Fig. 4 Output voltage wave form of 9-level

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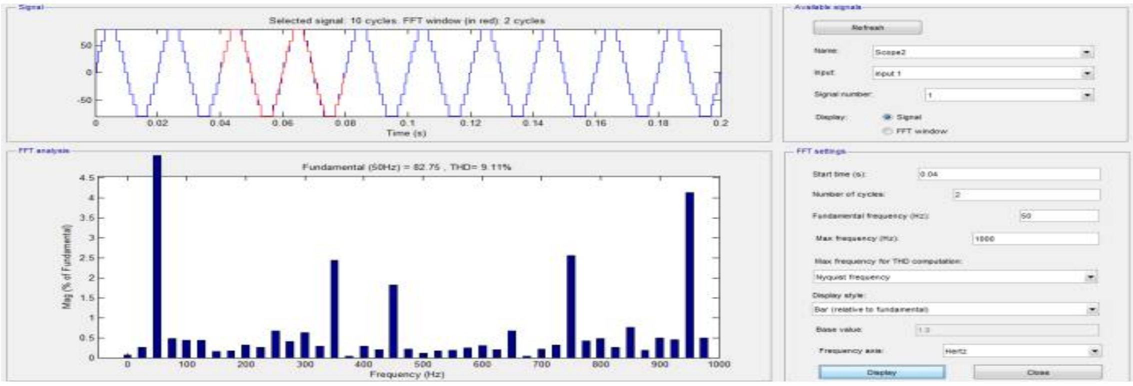

Fig. 5 FFT analysis of 9-level

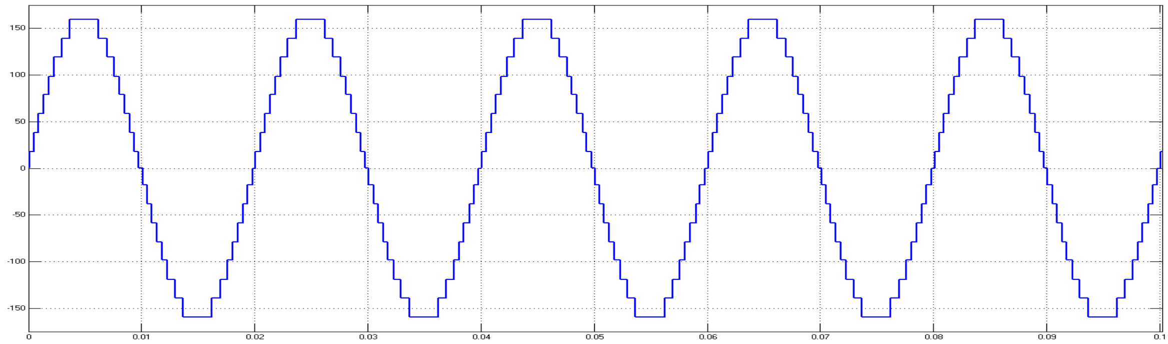

Fig. 6 Output voltage waveform of 17-level

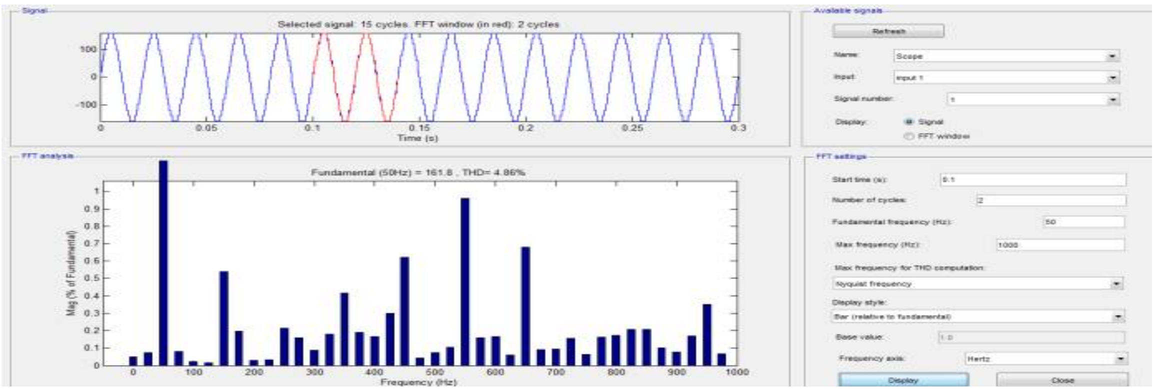

Fig. 7 FFT analysis of 17-level

The THD of 17-level hybrid MLI is within the IEEE standard as shown in figure 7.

V. CONCLUSION

In this paper the EAC technique is implemented with this method of calculation of switching angles we can find the best switching angles. No need of solving complex non-linear equations and without writing the MATLAB program for GA and NR. No need of assuming initial angles for NR. We achieved 46.65% reduction in the THD from 9-level to 17-level with resistive load.

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