ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 3, March 2017

A New Hybrid Multi Level Inverter with a New Switching Technique

[1] Adapala Tejasree [2] I Siva Prasad
[1]M.Tech (PEDR), Department of Electrical& Electronics Engineering, SPMVV-Andhra Pradesh.
[2]Academic Consultant, Department of Electrical& Electronics Engineering, SPMVV-Andhra Pradesh.

Abstract: — **Multilevel inverters have been an attractive topology for academia as well as industry in the recent decade for high power and medium voltage energy control. An asymmetric multilevel inverter, a new topology increases the level of output with reduced lower order harmonics and total harmonic distortion. In this paper, a new multi-level inverter (MLI) is introduced. This paper mainly focusing on reduction of Total Harmonic Distortion (THD). By adding one step voltage to the conventional MLI to increase number of levels without increasing the number of switches and to achieve minimum THD with simple switching technique called equal area criteria (EAC). By calculating switching angles at which the power switch should operate to eliminate lower order harmonics. In conventional method (symmetrical voltage sources), we need nineteen power switches to get 31-level. But in proposed MLI only eight power switches we can get up to 31-level with V_1:2V_1:4V_1:8v1 voltage ratios and grate reduction of THD with in IEEE standards. The proposed 31-level inverter is simulated with resistive load using MATLAB/Simulink and the simulation results shown for 31-level.**

Index Terms— **Multi Level Inverter (MLI), Equal Area Criteria (EAC), Total Harmonic Distortion (THD)**

I. INTRODUCTION

In last two decades the application of power conversion is rapidly increased. The conversion of power is mainly exists in two forms, one is rectification i.e., AC-DC to run DC motors and to store DC power using batteries, and second is inverter operation i.e., DC-AC. Depending upon the application we are converting the electrical power. For emergency services, stand -alone solar system requires inverter to convert DC power to AC power to run the AC loads like Induction Motor. Most of the loads are AC loads. So there is a need of inverter operation where the power cut problems are more, to achieve uninterrupted power supply for emergency services i.e., hospitalities we need inverter operation. Up to now there are so many topologies and different switching techniques proposed for low and high power applications [1], [6]. In this paper the simple switching technique is implemented called Equal Area Criteria (EAC), by dividing half of the fundamental sine wave with required number of output voltage levels. With the help of Equal Area Criteria method we can calculate effective switching angles to reduce lower order harmonic effect on the fundamental wave. In Hybrid conventional MLI with symmetrical voltage sources we need fifteen series switches to get 31-level [2], [6], we know when devices are connecting in series the overall reliability of the system will reduces. To increase reliability we are using less series switches with asymmetrical voltage sources to get same number of levels as before. In this paper, to get 31-level with less THD, we require only four power switches in level generation cell (LGC) and four in polarity generation cell ((PGC) i.e., H-bridge)) with eight switches we can generate 31-levels. In cascaded H-bridge with asymmetrical sources we require more switches to get same levels. But in proposed MLI there is a reduction in both number of switches and THD compared to other switching techniques [3], [6].

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,

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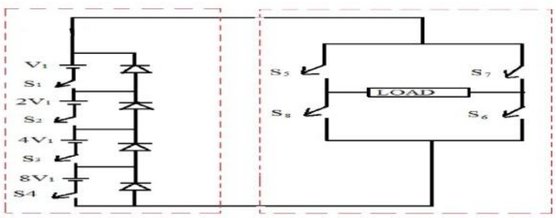

Level generating cell ***Polarity generating cell***

Fig. 1 Proposed 31-level MLI with asymmetrical sources

Here, V_1 is step voltage and the voltage ratio of asymmetrical sources is shown below,
$V_1 : 2V_1 : 4V_1 : 8v1$

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 31-level pulsating DC and the frequency of voltage wave is two times of output voltage frequency [6].

III. SWITCHING TECHNIQUE

Even though we have so many switching techniques among all, the best way to get minimum THD is selective harmonic elimination (SHE) [6]. By solving nonlinear equations is given below,

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

Here, V_{dc} is step voltage, V_F is fundamental voltage and theta is switching angle.

Solving above non-linear equation is easy if N is small value. But in the case of MLI the number of levels is high, in that case solving such a big non-linear equations is very difficult. But we can solve these equations by iterative manner. These types of equations can be solved by writing program in MATLAB with genetic algorithm (GA) [4] or Newton-Rapson (NR) methods [5], [6]. The difficulty in NR is the initial angle guess and the modulation index range varies with initial angle values. This problem can overcome by GA method. But the length of the program and number of iterations required more compared to NR. In this paper the simple technique called EAC is implemented to finding the initial values and these initial switching angles are enough to get minimum THD for any number of levels. The EAC is a natural method of finding the best switching angles [6], [7]. By dividing half of fundamental sine wave horizontally and vertically with step voltage and time (ms) respectively.

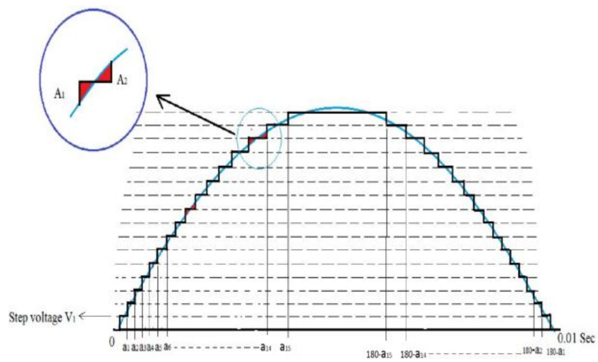

Fig. 2 Equal Area Criteria (EAC) switching technique

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[6].
Here, $a_1, a_2, a_3, \ldots . a_n$are the switching angles for N-level MLI. All the angles should be $<90^0$.

$$\mathbf{0<a_1<a_2<a_3<a_4<a_5<a_6<a_7 - - - - a_n<90^0}$$

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

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)] x [2 x fundamental frequency]] x 180^0
The switching angles for 31-level is given below,
$a_1=2^0$, $a_2=6^0$, $a_3=10^0$, $a_4=14^0$, $a_5=18^0$, $a_6=22^0$, $a_7=26^0$, $a_8=30^0$, $a_9=35^0$, $a_{10}=40^0$, $a_{11}=45^0$, $a_{12}=51^0$, $a_{13}=57^0$, $a_{14}=64^0$ $a_{15}=74^0$

We can calculate switching angles for N number of levels. These angles can also be useful for initial guess in NR. With the above switching angles for 31-level, the THD is 2.85%. Herethe sinusoidal pulse width modulation technique (SPWM) can be used for controlling H-bridge switches [6].

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ISSN (Online) 2395-2717

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Table-1: Switching sequence for proposed MLI

S.NO	S1	S2	S3	S4	S5	S6	S7	S8	Output voltage
1	1	1	1	1	1	1	0	0	15V
2	1	1	1	1	1	1	0	0	14V
3	1	1	0	1	1	1	0	0	13V
4	1	1	0	0	1	1	0	0	12V
5	1	0	1	1	1	1	0	0	11V
6	1	0	1	0	1	1	0	0	10V
7	1	0	0	1	1	1	0	0	9V
8	1	0	0	0	1	1	0	0	8V
9	0	1	1	1	1	1	0	0	7V
10	0	1	1	0	1	1	0	0	6V
11	0	1	0	1	1	1	0	0	5V
12	0	1	0	0	1	1	0	0	4V
13	0	0	1	1	1	1	0	0	3V
14	0	0	1	0	1	1	0	0	2V
15	0	0	0	1	1	1	0	0	1V
16	0	0	0	0	1	1	0	0	0V
17	0	0	0	1	0	0	1	1	-1V
18	0	0	1	0	0	0	1	1	-2V
19	0	0	1	1	0	0	1	1	-3V
20	0	1	0	0	0	0	1	1	-4V
21	0	1	0	1	0	0	1	1	-5V
22	0	1	1	0	0	0	1	1	-6V
23	0	1	1	1	0	0	1	1	-7V
24	1	0	0	0	0	0	1	1	-8V
25	1	0	0	1	0	0	1	1	-9V
26	1	0	1	0	0	0	1	1	-10V
27	1	0	1	1	0	0	1	1	-11V
28	1	1	0	0	0	0	1	1	-12V
29	1	1	0	1	0	0	1	1	-13V
30	1	1	1	0	0	0	1	1	-14V
31	1	1	1	1	0	0	1	1	-15V

IV. SIMULATION RESULTS

Hybrid MLI simulation circuit with resistive load is as shown below

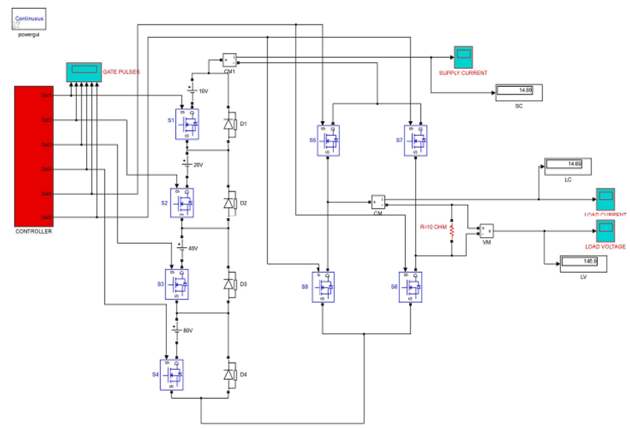

Fig. 3 Simulation circuit of proposed 31- level inverter

After calculation of switching angles we used pulse generators for LGC to Switch ON the switches at calculated switching angles and for H-bridge SPWM. The THD is more in conventional 31-level MLI with asymmetrical sources [6], [8], [9] compared to proposed switching technique. The value of THD is observed with the help of FFT analysis using MATLAB/Simulink software for 31-level with resistive load of 50ohms. We achieved The THD value of the above levels is 2.85%within the IEEE standard. The output voltage wave forms, FFT analysis and switching gate.pulsesare shown in below fig.

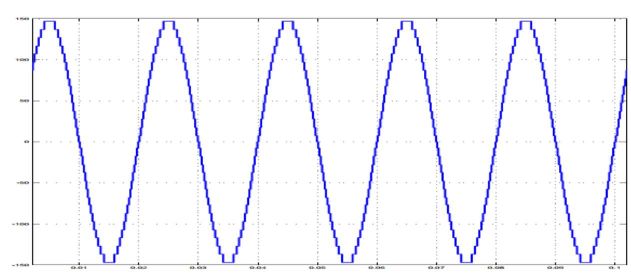

Fig. 4 Output voltage wave form of 31-level inverter

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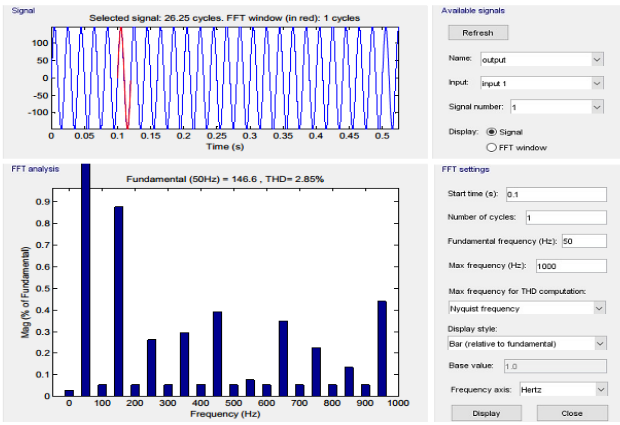

Fig. 5 FFT analysis of 31-level inverter

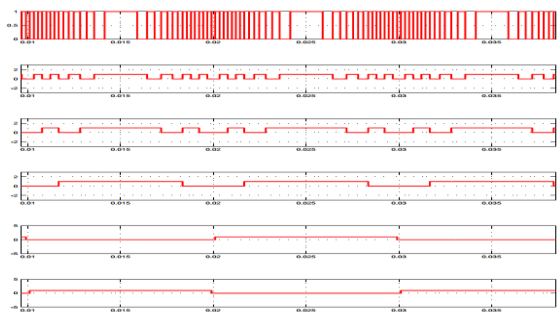

Fig. 6 Gate pulses for 31-level inverter

V. CONCLUSION

In this paper a new switching technique for 31-level inverter is presented. With this simple method we can easily calculate 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 guessing initial angles [6]. With this EAC technique we achieved 2.85% THD with resistive load for 31-level.

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