A Hybrid Multi Level Inverter with Equal Area Criteria Switching Technique

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ABSTRACT

In this paper, a hybrid MLI with reduced number of switches with asymmetrical voltage sources by equal area criteria (EAC) switching technique. By calculating switching angles at which the power switch should operate to eliminate lower order harmonics. The proposed MLI requires one Level generating cell (series-parallel combination of power switch, power diode and voltage sources) and one Polarity generating cell (H-bridge). In conventional method (symmetrical voltage sources), we need eleven power switches to get 15-level. But in proposed MLI with only seven power switches we can get up to 15-level with V_1:$2V_1$:$4V_1$ voltage ratios and grate reduction of THD nearly to IEEE standards. The proposed 15-level inverter is simulated with resistive load using MATLAB/Simulink and the simulation results shown for 7, 15-levels.

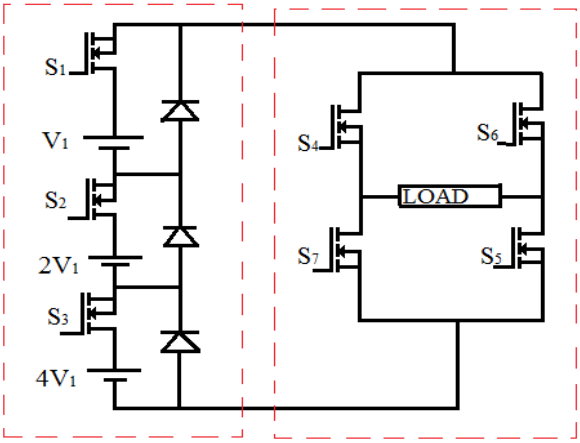
Keywords: *Multi Level Inverter (MLI), Total Harmonic Distortion (THD), Equal Area Criteria (EAC).*

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]. 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 seven series switches to get fifteen level [2], 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 15-level with less THD, we require only three power switches in level generation cell (LGC) and four in polarity generation cell ((PGC) i.e., H-bridge)) with seven switches we can generate fifteen 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].

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,



Level generating cell Polarity generating cell

Fig. 1 Proposed 15-level MLI with asymmetrical sources

Here, V_1 is step voltage and the voltage ratio of asymmetrical sources is shown below,

$$V_1 : 2V_1 : 4V_1$$

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 fifteen level pulsating 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 selective harmonic elimination (SHE). By solving non-linear 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]. 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]. By dividing half of fundamental sine wave horizontally and vertically with step voltage and time (ms) respectively.

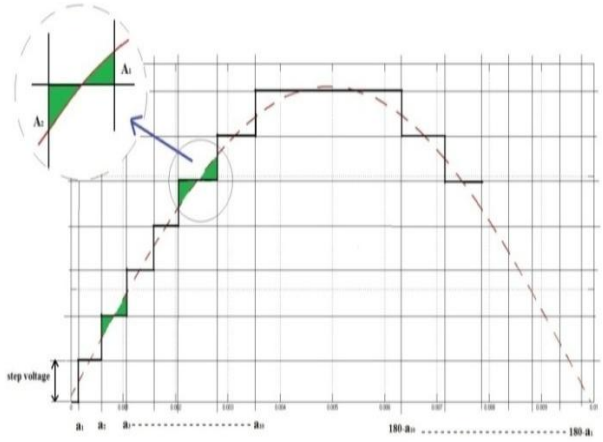


Fig. 2 Equal Area Criteria (EAC) switching technique

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. 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)]*[2*fundamental frequency]]*180^0

The switching angles for 7-level is given below,

$a_1=8^0$, $a_2=27^0$, $a_3=51^0$

The switching angles for 15-level is given below,

$a_1=3^0$, $a_2=10^0$, $a_3=19^0$, $a_4=28^0$, $a_5=37^0$, $a_6=50^0$, $a_7=63^0$

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 7-level, 15-level the THD is 11.83% and 5.39% THD. The sinusoidal pulse width modulation technique (SPWM) can be used for controlling H-bridge switches as shown below [7].

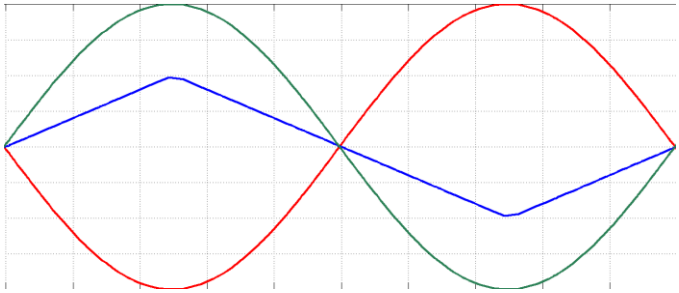


Fig. 3 SPWM for H-bridge

TABLE-1 Switching sequence for proposed 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	7V
2	1	1	0	1	1	0	0	6V
3	1	0	1	1	1	0	0	5V
4	1	0	0	1	1	0	0	4V
5	0	1	1	1	1	0	0	3V
6	0	1	0	1	1	0	0	2V
7	0	0	1	1	1	0	0	1V
8	0	0	0	1	1	0	0	0V
9	0	0	1	0	0	1	1	1V
10	0	1	0	0	0	1	1	-2V
11	0	1	1	0	0	1	1	-3V
12	1	0	0	0	0	1	1	-4V
13	1	0	1	0	0	1	1	-5V
14	1	1	0	0	0	1	1	-6V
15	1	1	1	0	0	1	1	-7V

IV. SIMULATION RESULTS

Hybrid MLI simulation circuit with resistive load is as shown below

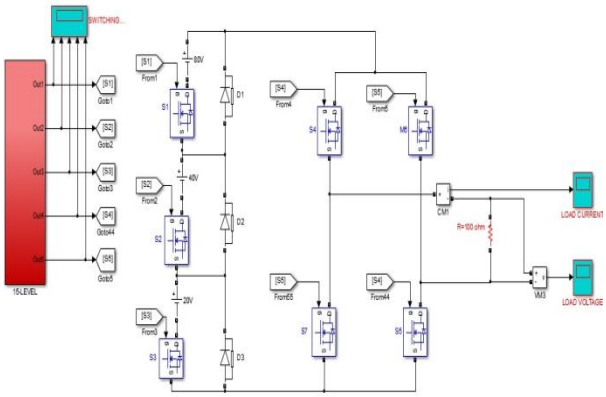


Fig. 4 Simulation circuit of proposed Hybrid 15- level inverter

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 7 and 15-level MLI with asymmetrical sources [8], [9] compared to proposed switching technique. The value of THD is observed with the help of FFT analysis using MATLAB/simulink software for 7 and 15-level with resistive load of 100ohms. The THD of the above levels are 11.83% and 5.39% respectively. The output voltage wave forms are shown below fig.

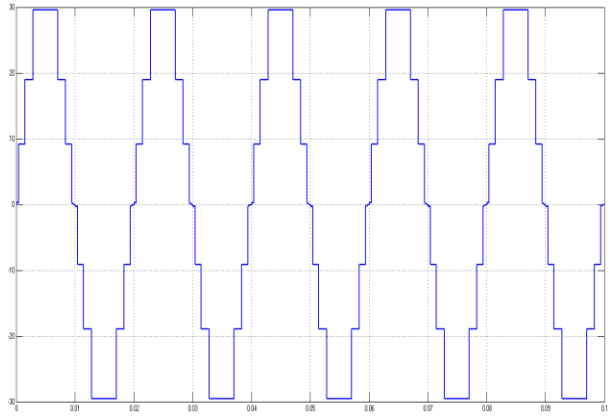


Fig. 5 Output voltage wave form of 7-level

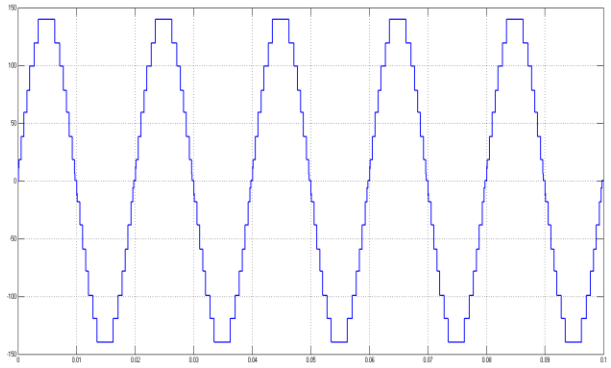


Fig. 6 Output voltage wave form of 15-level MLI

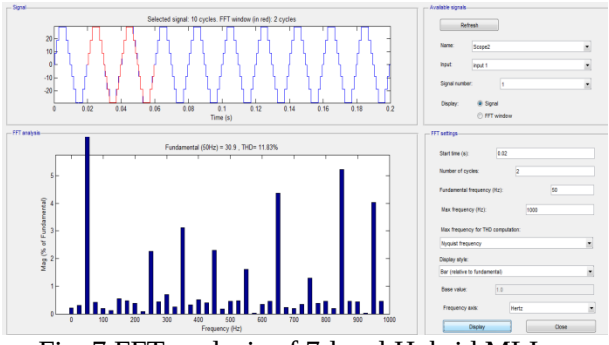


Fig. 7 FFT analysis of 7-level Hybrid MLI

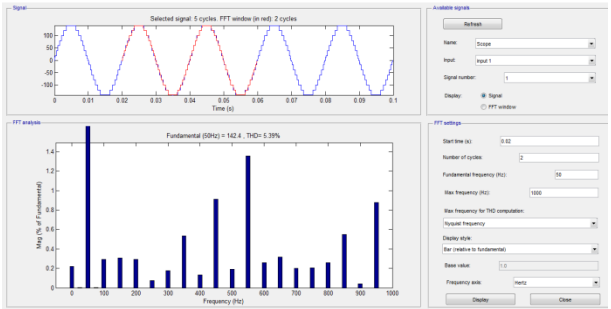


Fig. 8 FFT analysis of 15-level Hybrid MLI

V. CONCLUSION

In this paper the simple switching technique is implemented. With this natural method of calculation of the switching angles 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. With this EAC technique for 15-level with resistive load we got the THD nearer to IEEE standard value.

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