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A NEW NOVEL MULTILEVEL INVERTER TOPOLOGY WITH PV CONNECTED SYSTEMS BY HARMONIC ELIMINATION METHOD

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Abstract

Multilevel inverter is one of the most modern emerged and popular type of progress alternative in high power applications. This paper focuses on improving the efficiency of the multilevel inverter and quality of output voltage waveform from PV sources. Here the two techniques for enhancing the quality of the output voltage and efficiency are considered. First method introduces the reduced number of switches compared to other and conventional cascaded H-bridge multilevel inverter for the same level of output voltage. Second method eliminates the lower order harmonics with selective harmonic elimination stepped waveform (SHESW). Fundamental switching scheme is used to control the power electronics switches in the inverter. The novel topology is suitable for any number of levels. Selective Harmonics Elimination topology using nine power electronic switches for eleven-level inverter with five PV sources is developed. By using this topology and losses of the proposed inverter is reduced and efficiency is enhanced significantly. This paper is particularly focuses on eleven-level inverter. Simulation work is done using the MATLAB software which validates the proposed method and finally THD comparison is presented for analysis.

I. INTRODUCTION

Multilevel converters are mainly utilized to synthesis a desired single- or three-phase voltage waveform. The desired multi-staircase output voltage is obtained by combining several conventional dc voltage sources. Solar cells, fuel cells, batteries and ultra capacitors are the most common independent sources used.

Diode-clamped multilevel converters are used in conventional high-power ac motor drive applications like conveyors, pumps, fans, and mills. They are also utilized in oil, gas, metals, power, mining, water, marine, and chemical industries. They have also been reported to be used in a back-to-back configuration for regenerative applications.

Flying capacitor multilevel converters have been used in high bandwidth high-switching frequency applications such as medium-voltage traction drives. Finally, cascaded H bridge multilevel converters have been applied where high power and power quality are essential, for example, static synchronous compensators active filter and reactive power compensation applications, photovoltaic power conversion, uninterruptible power supplies, and magnetic resonance imaging. Furthermore, one of the growing applications for multilevel motor drives is

electric and hybrid power trains.

For increasing voltage levels the number of switches also will increase in number. Hence the voltage stresses and switching losses will increase and the circuit will becomes complex. By using the proposed topology number of switches will reduce significantly and hence the efficiency will improve.

In high power applications, the harmonic content of the output waveforms has to be reduced as much as possible in order to avoid distortion in the grid and to reach the maximum energy efficiency. The challenge associated with techniques is to obtain the analytical solutions of the non-linear transcendental equations that contain trigonometric terms which naturally exhibit multiple sets of solutions. Generally the lower order harmonics are causing more effects when compared to the higher order harmonics. It is big challenge for any researcher to eliminate the third order harmonics using simple techniques. For a motor load its effects are high. This paper proposes method to eliminate lower order harmonics.

In this paper Selective Harmonics Elimination technique is used. Fifth, seventh, eleventh and thirteenth harmonics are eliminated by using this technique. The transcendental non-linear equations are solved using the numerical technique called Newton Raphson method. Traditional two and three level inverters are investigated with the harmonic analysis and cascaded H-bridge eleven-level inverter is modeled and harmonic analysis is carried out. Finally the proposed topology is presented with the implementation of SHE. The THD values for the Traditional, Conventional and Proposed inverters are compared and analyzed.

II.H-BRIDGE MULTILEVEL INVERTER

The traditional two or three levels inverter does not completely eliminate the unwanted harmonics in the output waveform. Therefore, using the multilevel inverter as an alternative to traditional PWM inverters is investigated.

In this topology the number of phase voltage levels at the converter terminals is 2N+1, where N is the number of cells or dc link voltages. In this topology, each cell has separate dc link capacitor and the voltage capacitor might differ among the cells. So, each power circuit needs just one dc voltage source. The number of dc link capacitors is proportional to the number of phase voltage levels. Each H-bridge cell may have positive, negative or zero voltage. Final output voltage is the sum of all H-bridge cell voltages and is symmetric with respect to neutral point, so the number of voltage levels is odd.

Cascaded H-bridge multilevel inverters typically use IGBT switches. These switches have low block voltage and high switching frequency.

Consider the eleven-level inverter; it requires 20 IGBT switches and five dc sources. The power circuit of inverter is shown in the figure.1. A cascaded H –bridges multilevel inverter is simply a series connection of multiple H-bridge inverters. Each H-bridge inverter has the same configuration as a typical single-phase full-bridge inverter.

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The cascaded H-bridges multilevel inverter introduces the idea of using Separate DC Sources (SDCSs) to produce an AC voltage waveform. Each inverter is connected to its own conventional DC source cascading the AC outputs of each H-bridge inverter, an AC voltage waveform is produced.

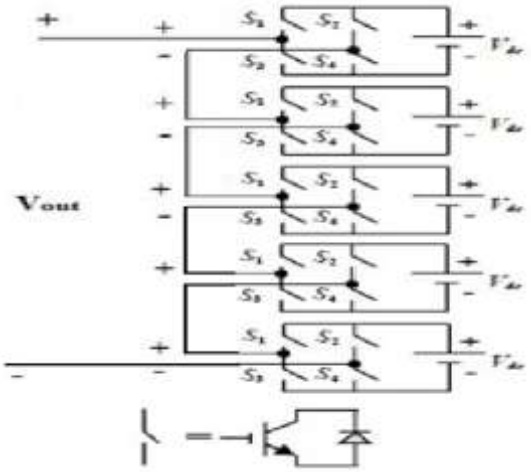

Fig.1. Cascaded H-bridge 11-level Inverter

By closing the appropriate switches, each H-bridge inverter can produce three different voltages: +Vdc, 0 and -Vdc.

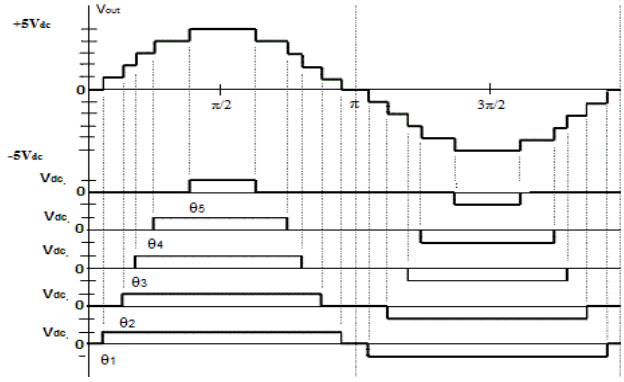

Fig.2. Output Voltage of cascaded H-bridge 11- level inverter

It is also possible to be modularized circuit layout and packaging because each level has the same structure, and there are no extra clamping diodes or voltage balancing capacitors. The number of switches is new topology.

This circuit is simulated using the MATLAB software. The results are shown in the later sections in detail.

III.PROPOSED NOVEL TOPOLOGY

The main objective is to produce the quality output voltage of the multilevel inverter with reduced number of switches. An important issue in multilevel inverter design is that the voltage waveform is near sinusoidal and the lower order harmonics are eliminated. A key concern in the

fundamental switching scheme is to determine the switching angles in order to produce the fundamental voltage without generating specific lower order harmonics.

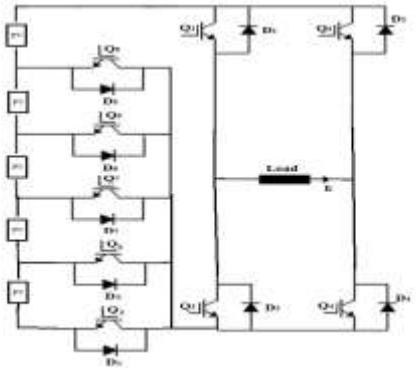

Fig.3. Proposed Power circuit for 11-level output

The proposed topology has the advantage of the reduced number of power switching devices, but on the expense of the high rating of the main four switches. Therefore, it is recommended for medium power applications.

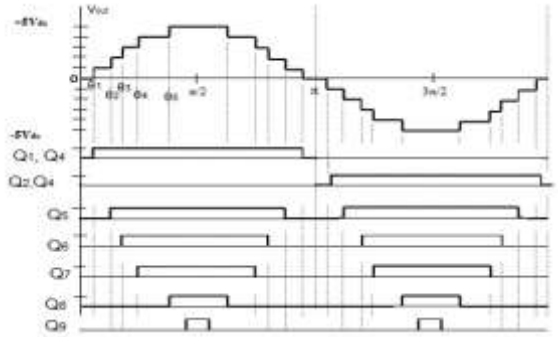

Fig.4. Waveforms of the proposed 11- level inverter

in figure.4. switching pattern for the various switches are explained. In this paper fundamental frequency switching scheme is employed which reduces the switching losses. Because the switching frequency is less in this method when compared to the other methods. Switching losses are directly proportional to the switching frequency.

IV.SELECTIVE HARMONICS ELIMINATION

The Selective Harmonic Elimination Stepped- Waveform (SHESW) technique is very suitable for a multilevel inverter circuit. Employing this technique along with the multilevel topology, the low Total Harmonic Distortion THD output waveform without any filter circuit is possible.

A. Fourier series and Harmonics Elimination theory

After applying Fourier theory to the output voltage waveform of multilevel converters, which is odd quarter wave symmetric, we can find the Fourier expression of the multilevel output

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voltage as (1). If the DC voltages are equal in the multilevel converter, the equation for the fundamental frequency switching control method can be expressed as:

$V(t)=\Sigma^{\infty}_{n=1,3,5...}4V_{dc}/n\pi(\cos(n\theta_1)+\cos(n\theta_2)+\cos(n\theta_3)+\ldots\ldots\ldots\ldots+\cos(n\theta_s))\sin(n\omega t)$ (1)

From the equation, it can be seen that the output voltage has no even harmonics because the output voltage waveform is odd quarter-wave symmetric. It also can be seen from (1) that the peak values of these odd harmonics are expressed in terms of the switching angles θ1, θ2,……. and θs. Furthermore, the harmonic equations produced from (1) are transcendental equations. Based on the harmonic elimination theory, if one wants to eliminate the n_{th} harmonic, then

$\cos(n\theta_1) + \cos(n\theta_2) + \cos(n\theta_3) + \ldots.. + \cos(n\theta_s) = 0$ (2)

That means to choose a series of switching angles to let the value of the n_{th} harmonic be zero. Therefore, an equation with *s* switching angles will be used to control the s different harmonic values. Generally, an equation with s switching angles is used to determine the fundamental frequency value, and to eliminate s-1 low order harmonics.

For an equation with five switching angles, (2) becomes

$V(t) = \Sigma^{\infty}_{n=1,3,5...}4V_{dc}/n\pi(\cos(n\theta_1)+\cos(n\theta_2)+\cos(n\theta_3)+\cos(n\theta_4)+(\cos(n\theta_5))\sin(n\omega t)$ (3)

B. Transcendental Equations to solve

In this paper we derived harmonic equations for eliminating the 5th, 7th , 11th and 13th order harmonics. The resulting harmonic equations are:

$\cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3) + \cos(\theta_4) + \cos(\theta_5) = \pi V_{1/4}Vdc$ (4)
$\cos(5\theta_1) + \cos(5\theta_2) + \cos(5\theta_3) + \cos(5\theta_4) + \cos(5\theta_5) = 0$ (5)
$\cos(7\theta_1) + \cos(7\theta_2) + \cos(7\theta_3) + \cos(7\theta_4) + \cos(7\theta_5) = 0$ (6)
$\cos(11\theta_1) + \cos(11\theta_2) + \cos(11\theta_3) + \cos(11\theta_4) + \cos(11\theta_5) = 0$ (7)
$\cos(13\theta_1) + \cos(13\theta_2) + \cos(13\theta_3) + \cos(13\theta_4) + \cos(13\theta_5) = 0$ (8)

To simplify the expression, (4) can be written as

$\cos(\theta_1) +\cos(\theta_2) + \cos(\theta_3) + \cos(\theta_4) + \cos(\theta_5) = m$ (9)

Where $m = \pi V_{1/4}Vdc$ (10)

These harmonic equations (4)-(8) are transcendental equations. They are difficult to solve without using some sort of numerical iterative technique. Here Newton -Raphson method is employed for solving these equations.

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The set of non-linear Transcendental Equations can be solved by iterative method such as Newton-Rapshon method. For example, using modulation index m of 0.8 obtains:

θ1 = 6.57°
θ2 = 18.97°
θ3 = 27.18°
θ4 = 45.14°
θ5 = 62.24°

V. SIMULATION WORK

A. Simulation of the conventional eleven -level inverter

This circuit consists of 20 IGBT switches with 5 equal dc sources. The gate pulses are generated by using the Gate pulses are generated from the pulse generators.

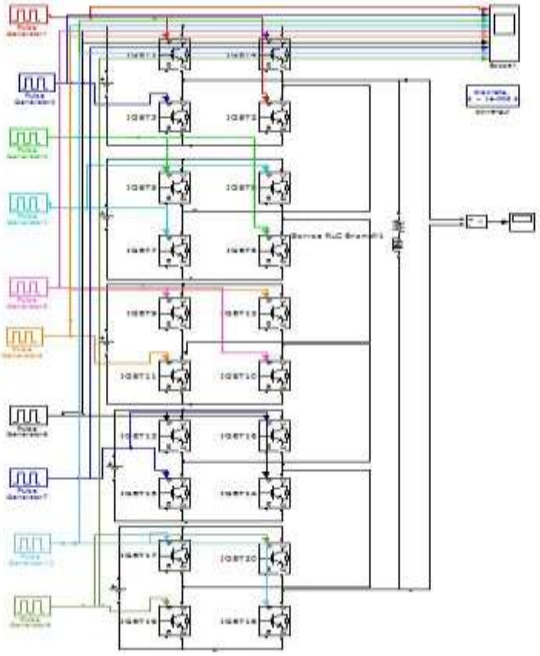

Fig.5. Simulation Model for conventional eleven-level Inverter

From the harmonic analysis of seven level output voltage of the 20 switch H-bridge inverter, the THD value is obtained as 26.6%.

B. Simulation of the Proposed Inverter Topology

The Simulink model diagram for the proposed circuit is shown in figure.6. It has only nine switches and five PV sources. The single phase asynchronous motor is used as load. Gate pulses

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are generated by the combination of relational and logical operators.

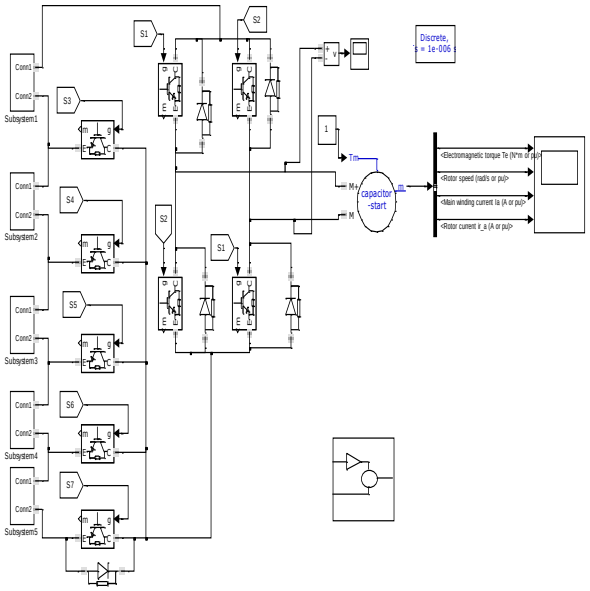

Fig.6. Simulation model for Proposed Inverter

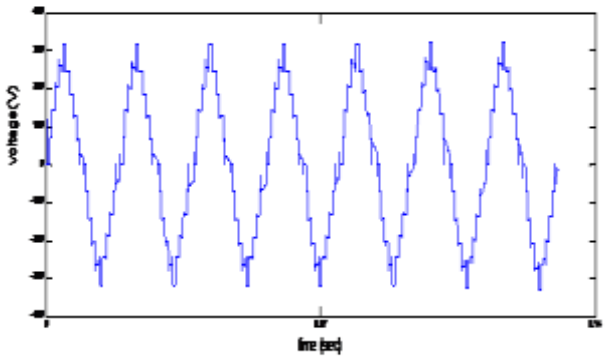

Fig.7. Eleven-level output voltage of proposed Inverter

From the figure.7 it is clear that eleven-level or five stepped waveform is obtained. Then harmonic analysis is carried out with the induction motor.

C. Results Analysis

Table.1. THD Comparison

Kind of the MLI	2 level MLI	3 level MLI	11 level conventional MLI with motor load	11 level proposed MLI with motor load
THD	46.37 %	29%	26.6%	16.5%

From the table.1. Different level inverters THD values are compared. The proposed inverter THD value is obtained as 16.5%, which is the best among all. This shows that quality of the eleven-level inverter is improved.

VI.CONCLUSION

Compared to typical PWM switching schemes, multilevel fundamental switching will lead to lower switching losses. As a result, using the multilevel fundamental frequency switching scheme will lead to increased efficiency.

This paper is presented a procedure to selectively eliminate certain harmonics in a multilevel inverter utilizing the multilevel fundamental frequency switching scheme.

For a novel H-bridges multilevel inverter utilizing five equal PV sources, most of the time the switching angles can be selected such that the output voltage THD is less than 20%. Thus by using the proposed scheme THD and switching losses are reduced.

The percentage of reduced number of switches is explained with the help of the table.2. Shown below

Table.2. Percentage Reduction of Switches

Inverter type		11 - level
Number of switches used	Cascaded H-bridge	20
	Proposed topology	9
% of switch reduction		55

From the table.2. The number of switches using in proposed topology is reduced 55% as compared to conventional multilevel inverter.

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