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Analysis and Simulation of Asymmetrical Cascaded H-Bridge Eleven Level Inverter

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Abstract – *This paper analyzes the performance of asymmetrical cascaded h-bridge eleven level inverter with photovoltaic cell as its input source. The inverter is capable of producing eleven levels of output-voltage levels from the dc supply voltage. From this analysis it is found that the total harmonic distortion of the system is low when compared to asymmetrical cascaded h-bridge nine level inverter. Hence the efficiency of the system will be improved. Also it uses less number of power semiconductor switches when compared to symmetrical cascaded h-bridge eleven level inverter. The analysis has been simulated using MATLAB. The simulated output shows very favorable result.*

Keywords: *Multilevel inverter, Cascaded H-Bridge inverter, Total Harmonic Distortion, Photovoltaic cell*

1. INTRODUCTION

In recent years, power electronics engineers have paid great attention to multilevel inverters as a new kind of power converter. Most multilevel inverters have an arrangement of switches and capacitor voltage sources. By a proper control of the switching devices, these can generate stepped output voltages with low harmonic distortions. These multilevel inverters are widely used in manufacturing factories and acquired public recognition as one of the new power converter fields because they can overcome the disadvantages of traditional inverters.[1]

Multilevel inverters can be divided into three remarkable topologies: diode clamped, flying capacitors, and cascaded H-bridge cells with separate DC sources. In addition in recent years, many topologies have been suggested to multilevel converter with a low number of switches and gate driver circuits. Compared with the traditional two-level voltage inverter, the main advantages of the multilevel inverter are a smaller output voltage step, lower harmonic components, a better electromagnetic compatibility and lower switching losses. The main disadvantages of the multilevel inverter are the use of a larger number of semiconductors and a complex control circuitry and needing the equilibrating of the voltage at the boundaries of capacitors.[2] The modulation methods used in multilevel inverters can be classified according to switching frequency. A very popular method in industrial applications is the classic carrier based sinusoidal pulse width modulation (SPWM) that uses the phase shifting technique to reduce the harmonics in the load voltage. Other methods that work with low switching frequencies generally perform one or two commutations of the power semiconductor switches during one cycle of the output voltages, generating a staircase waveform. Representatives of this family are multilevel selective harmonic elimination and space vector control.[3]

Modern industrial processes are based on a large amount of electronic devices such as programmable logic controllers and adjustable speed drives. Various power quality problems faced by these industrial and commercial customers. Custom power devices are introduced in the distribution system to deal with various power quality problems. Among power quality problems, voltage sags are more serious as they can cause customer equipment to malfunction or a production shutdown. An effective way of controlling the sags is to inject power into the system using DVR. The DVR is the best suited to protect sensitive loads against voltage disturbances, where it can inject a controllable voltage in series with the supply voltage to keep the voltage constant at the load terminals.[4]

This paper investigates the multilevel inverters and focuses on topologies where the input DC voltages are not same. These topologies are known as asymmetrical multilevel inverters. When the number of levels increases, the difference between output waveform and reference sinusoidal waveform would be reduced. Simulation results verify the theoretical consideration, too.

2. PHOTOVOLTAIC CELL

A Photovoltaic cell is a device used to convert solar radiation directly into electricity. It consists of two or more thin layers of semiconducting material, most commonly silicon. When the silicon is exposed to light , electrical charges are generated.[5] A PV cell is usually represented by an electrical equivalent one-diode model shown in figure.1.

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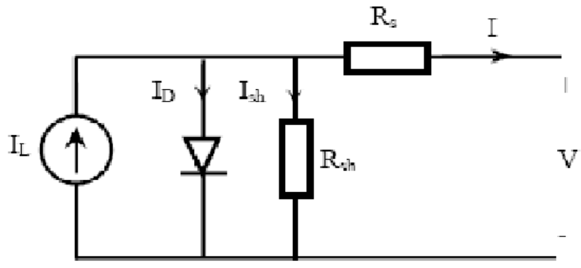

Figure 1: Single PV cell model

The model contains a current source, one diode, internal shunt resistance and a series resistance which represents the resistance inside each cell. The net current is the difference between the photo current and the normal diode current is given by the equation.[6].

$$Id = Io\left[e^{\frac{q(V+IRs)}{KT}} - 1\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$I = I_L - I_o\left[e^{\frac{q(V+IRs)}{KT}} - 1\right] - \frac{V+IRs}{Rsh} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where

I is the cell current (A).

q is the charge of electron (coul).

K is the Boltzmann's constant (j/K).

T is the cell temperature (K).

I_L is the photo current (A).

Io is the diode saturation current.(A)

Rs , Rsh are cell series and shunt resistances (ohms). V is the cell output voltage (V).

3. ASYMMETRICAL CASCADED H-BRIDGE INVERTER

Asymmetrical Cascaded H-Bridge eliminates large number of bulky transformers required by conventional multi level inverters, the clamping diodes required by diode clamped multilevel inverters and the bulky capacitors required by flying capacitor multilevel inverters. This method consists of a series connection of multiple H bridge inverters as shown in figure 2. Each H-bridge inverter has the same configuration as a typical single-phase full-bridge inverter. This method introduces the idea of using separate DC sources to produce an AC voltage waveform which is nearly sinusoidal. Each H bridge inverter is connected to its own DC source. By cascading the output voltage of each H-bridge inverter, a stepped voltage waveform is produced. If the number of H-bridges is N, the voltage output is obtained by summing the output voltage of bridges as shown in equation.

If ACMLI has N no. of H-Bridges,

The output voltage could be expressed as ; $Vo\,(t) = Vo1\,(t) + Vo2\,(t) + \ldots.. + Vo\,N\,(t)$ (1)

Where, $Vo1\,(t)$,$Vo2\,(t)$, ... $Vo\,N\,(t)$ are the output of individual H-bridge.

In ACMLI DC voltage with ratio binary and ternary are the most popular. In binary progression within H-Bridge inverters, the DC voltages having ratio 1: 2: 4: 8. . : 2N and the maximum voltage output would be (2^N-1) V dc and the voltage levels will be (2^{N+1}-1). While in the ternary progression the amplitude of DC voltages having ratio 1: 3: 9: 27. . : 3N and the maximum output voltage reaches to ((3^N- 1)/2) V dc and the voltage levels will be(3^N) .[7] Figure 3 shows the output voltage waveform of an 11-level cascade inverter.

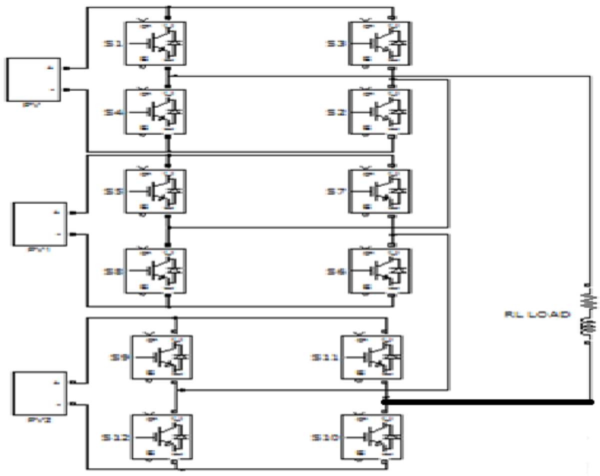

Figure 2: Proposed Asymmetrical cascaded h-bridge 11 level inverter

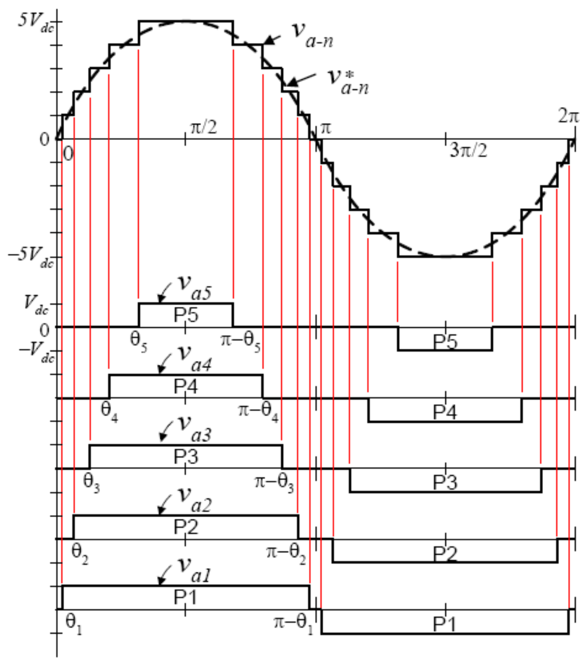

Figure 3: Output voltage waveform of an 11-level cascade inverter

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4. PWM TECHNIQUE

Several modulation strategies have been developed for multilevel inverters.[8]-[9] The most commonly used is the multi carrier PWM technique. The principle of the multicarrier PWM is based on a comparison of a sinusoidal reference waveform with triangular carrier waveforms. m-1 carriers are required to generate m levels. The carriers are in continuous bands around the reference zero. They have the same amplitude Ac and the same frequency fc. At each instant, the result of the comparison is 1 if the triangular carrier is greater than the reference signal and 0 otherwise. The output of the modulator is the sum of the different comparisons which represents the voltage level.

5. SIMULATION RESULTS

In this paper, the simulation model is developed with MATLAB/SIMULINK. The simulink model of the proposed inverter is shown in figure 4. The proposed circuit needs independent dc source which is supplied from photovoltaic cell. Simulated line voltage and THD analysis for asymmetrical cascaded h-bridge eleven level inverter is shown in figure 5 and 6. From the simulated analysis the THD content of the asymmetrical topology is low (18.53%) when compared to symmetrical cascaded h-bridge nine level inverter (24.64%) as shown in figure 7. Also it uses less number of power semiconductor switches (12 nos.) when compared to symmetrical cascaded h-bridge eleven level inverter (20 nos.).

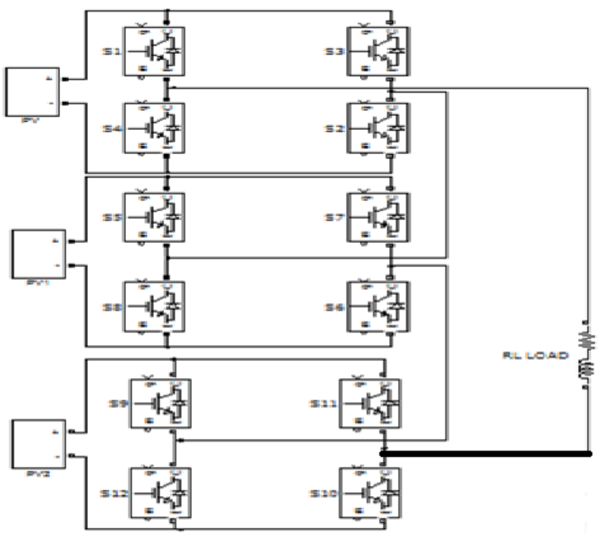

Figure 4: Simu link model of the proposed inverter

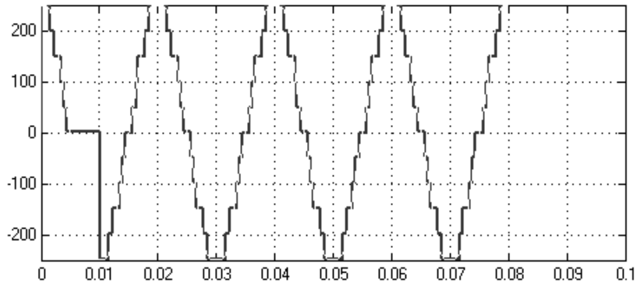

Figure 5: Output voltage waveform

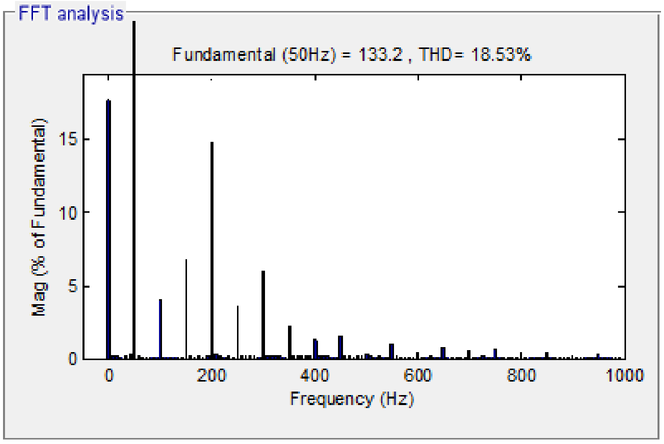

Figure 6: THD analysis(proposed)

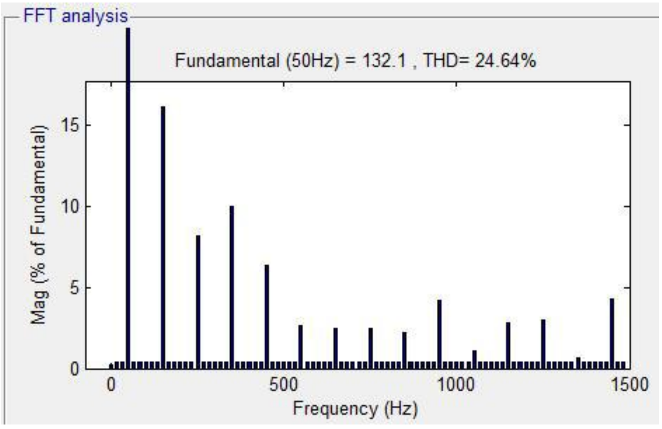

Figure 7: THD analysis(conventional)

6. CONCLUSION

In the present work, performance of asymmetrical cascaded h-bridge eleven level inverter with photovoltaic cell as its input source by using multicarrier pwm technique has been analyzed by the MATLAB/Simulink. From the simulated analysis the total harmonic distortion of the system is low when compared to asymmetrical cascaded h-bridge nine level inverter. Hence we could achieve the improved efficiency of

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the system. The future work may be focused on implementing closed loop control to achieve better performance.

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