A Solar-Integrated 25-Level H-Bridge Multilevel Inverter

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Abstract - *One of the most crucial components in a solar energy system is an inverter. A multilevel inverter is frequently employed as the connection point between a renewable energy source and the electrical grid. Due to its capacity to operate at high voltage, little switching losses, low dv/dt stress, which results in low presence of electromagnetic interference (EMI) in output, improved performance, and obtained good power quality, multilevel inverters have drawn more attention from researchers. In the design of multilevel inverters today, power electronics devices are increasingly used. However, the multilevel inverter's power electronics interface leads to harmonic distortion and poor power quality. Over the past 20 years, various multilayer inverter designs have been put out in an effort to reduce these harmonic distortions. A single-phase solar-integrated 25-level H-bridge multilevel inverter is suggested in this paper. To meet load demand, it is based on twelve independent solar PV arrays. It is recommended to use a hybrid topology to reduce the number of components and harmonics (like clamping diodes, DC Bus capacitor). The proposed model has been put into practice using MATLAB/Simulink.*

***Key Words*: Harmonics, Multilevel inverter, 25-level, Photovoltaic array (PV), MATLAB**

1.INTRODUCTION

In the modern era, renewable energy sources have drawn a lot of attention. due to the lack of pollution and the abundance of reserves. Consequently, the public usually supports the use of renewable energy. The multilevel inverter is a type of converter that can use dc voltages as inputs to generate the appropriate alternating voltage level at the output. Applications for multilevel inverters have primarily been found in renewable energy systems. the enhanced performance, low dv/dt stress power electronics switches, and innovative switching topologies have all led to increased multilayer inverter use in unconventional energy systems. The multilayer inverter produced high-quality waveforms with the least number of harmonics, which increased their appeal to PV systems. Numerous inverters with various topologies have been developed by researchers in order to attain high efficiency and high reliability. These inverters can be used in applications requiring medium and high power. Multilevel inverters provide the right solution for the PV system in order to achieve high performance of renewable energy generation. This suggested setup had twelve standalone solar PV arrays and a 25-level H-bridge multilevel inverter. It is advised to use a cascading system with sinusoidal PWM control to achieve various voltage levels at the inverter's output side. The suggested modal's technical terms are shown in Table 1.1.

Table 1.1. Technical Terms of Components

Sr.no	Components	Specification
1	IGBT switches	Internal resistance R_{on}=1e-3ohms Snubber resistance R_s=1e5 ohms
2	Solal panel (single panel)	Maximum output power=287.5W Voltage at mpp(V_{mmp})=28.75V Current at mpp(i_{mpp})=10A Cells per module= 54cells

For proposed model, constant solar irradiance is assumed i.e.,1000Wm^{-2} and fixed atmospheric temperature i.e.,25^{0}C

2.LITERATURE SURVEY

The study by S. Mohapatra et al. proposed inverter topologies. In that, the author looked at various switching topologies, including, flying clamped inverter, neutral point clamped inverter H-bridge inverter with cascading NPC inverters, FC inverters, and CHB inverters all require more parts than the inverter that is being proposed. It has a complicated circuit and high switching loss. A hybrid cascaded multilevel inverter topology with fewer switching elements and dc sources has been designed. Without employing the technique of pulse width modulation, the author introduced the hybrid inverter. Results indicate output with reduced harmonic content [1].

The suggested approach uses a single PV source that operates in an asymmetrical manner. This mode provides eight positive and eight negative voltage levels (for a total of 17 levels, including 0V) without the use of a separate switching mechanism. Eleven switches are provided in a cascading pattern to produce various voltage levels from a single PV source. The output of a dc source is increased using a dc-dc sumo converter. This increased the dc source's output that the inverter received. The output side of an asymmetrical mode of operation has seventeen voltage levels. The power electronics switches are controlled by an Atmega16 microprocessor. The proposed model is created using MOSFET. Simulink takes into account the R load. The proposed inverter has a very low total harmonic distortion, per the findings of the simulation [2].

Ajmal Farooq et al. introduced new topology for low harmonic distortion. The authors proposed a novel topology for a multilevel inverter with seventeen levels for high power applications and fewest possible components. Low switching loss and low dv/dt stress are the outcomes of that. Two bidirectional switches, six unidirectional switches, and four DC sources make up the design of the suggested inverter. The suggested model provides seventeen voltage levels, comprising eight positive, eight negative, and one zero voltage level, using ten IGBTs and four standalone dc sources. The voltage of DC sources is chosen using a 1:3 ratio. If V 1 is 25 V, then V 2 will be 75 V, which is three times V 1. The PWM approach is sinusoidal. Capacitor is used to compress harmonics. Proposed model has the advantaged of minimum harmonic distortion with in cascaded hybrid inverter with sine pulse width modulation technique [3].

Felipe Bovolini and Grigoletto propose a new five-level architecture for an inverter with lower harmonic content and no transformer in their paper, The PV system uses this topology. The inverter topology that is suggested utilizes reactive power. This proposed model provides a five-level single phase transformer- less inverter using a straight forward modulation mechanism. Circuits employ capacitors. Grid neutral point is connected to PV stack negative point to achieve minimal leakage current, or virtually nil [4].

N. Kalaiarasi et al. discuss hybrid architecture for nine level inverters for photovoltaic applications in their paper, this suggested model employed a cascaded configuration of half bridge inverters connected in series. Calculated output at the AC voltage level is 2*n+1.where, total number of sources represented by n. The total of all inverter output voltages is the inverter's overall output. In comparison to traditional VSI and CSI, staircase output is achieved with lesser harmonics and higher output voltage [5].

Different topologies for inverter operation and control strategies for multilevel inverters were represented by Zina Boussada et al. Diode Clamped Inverter Topology is one of them. The existence of a dc bus on phase reduces the need for capacitors. This makes it impossible to employ this topology. Topology for Flying Clamped Capacitors. In that, there is only one dc source required in this setup. The advantage is that balance flying capacitors and clamping diodes are not required. Second one is Cascaded Topology. This topology is pretty straightforward. Based on a full- bridge converter coupled in a cascaded configuration, this topology creates a bridge converter. High power levels benefit greatly from this topology [6].

The suggested multilayer inverter is designed utilizing a T-type inverter with sub switches of H-Bridges, as described by c. Dhanamjayulu et. al. It is possible to obtain 17 voltage levels with various loads using the staircase PWM approach. Applications involving facts and unconventional energy can use the proposed inverter. Less power switches were needed in the proposed model, which led to lower costs and better performance. More efficiency was obtained for both linear and non-linear loads [7].

T Raju J et al. offer new topologies designed for multilevel inverters to generate 11 levels of voltage at the output side in their research paper. his topology recommended an inverter with fewer DC sources. As a result, in simple inverter circuit with good output performance. Harmonics present in inverter reduced by using PWM waveform technique [8].

3. PROPOSED MODAL

The most popular renewable energy source used to supply electricity is solar energy. owing to the appealing quality of solar energy. The suggested model includes a photovoltaic system with twelve independent solar PV arrays that uses to obtained a 25-level H-bridge multilevel inverter. To fulfill the maximum demand of load twelve standalone PV array is used Twelve hybrid bridges with a particular switching topology are used to convert the input dc voltage to an ac voltage with different levels on the output side. Switching losses can be reduced by employing IGBT. Figure 3.1 is a block diagram of the proposed model of the 25-level HMLI. The suggested 25-level hybrid cascaded multilevel inverter's output is seen in Figure 3.2.PWM controlled method is used for switching topology with reference sine wave.

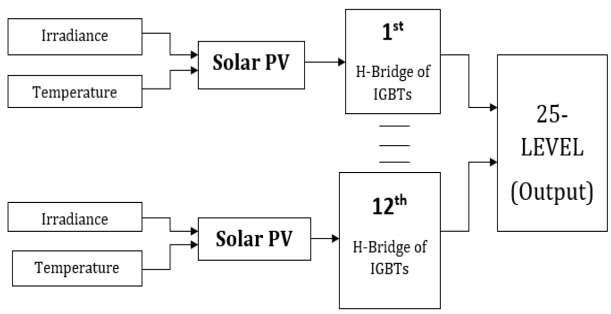

Fig- 3.1. Block Diagram of 25-Level HMLI

Twelve bridges are used to create the twenty-five voltage levels on the output side. There are four separate IGBT switches in each. Forty- eight IGBTs in total are employed to produce 25 levels of output. A consistent sinusoidal reference signal is employed with the suggested modal PWM scheme. The output voltage may vary as a result of atmospheric factors. However, in order to prevent temperature variations, PV arrays operate on continuous irradiance and temperature. The technical information about the components is shown in table number 1. values of 24-hour temperature variations. However, a constant solar irradiation value of 1000Wm-2C and a fixed temperature value of 25 °C are assumed. IGBTs have very little power loss when utilized as power electronics switches. All PV arrays are fed with 1000Wm-2 of irradiance, and their operating temperature is 25°C. Twenty-five voltage levels is obtained with minimum harmonics contains that is 3.36 percent.

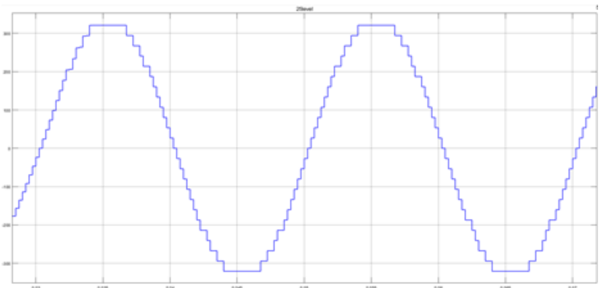

Fig 3.2. Output of Proposed 25-Level HMLI

A. DESIGNED OF PV ARRAY

Through the photovoltaic effect, the solar system's light energy is transformed into electrical energy. When solar radiation strikes a PV array (solar cell), current flows through them. The proposed modal PV array is modelled for internal parameters, ambient temperature, and sun light intensity [9]. Figure 3.3 depicts the PV array's comparable circuit (solar cell).

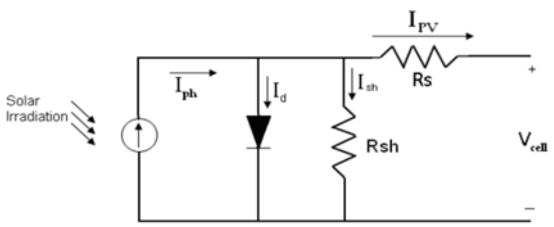

Fig 3.3. Solar Cell equivalent circuit.

From above circuit, total current given by,

$$I = I_{SH}+I_D+I_L \quad (1)$$

Where,

I = Output current of solar cell in Amperes

I_{ph}= Photo generated current in Amperes

I_{SH}= Current flowing in shunt resistance in Amperes

I_D= Diode Current in Amperes

The current is governed by Voltage across them,

$$V_1 = V + IR_S \quad (2)$$

Where,

V_1=Voltage across resistance and diodes in volts

V= Output terminals voltage in volts

I=Output current of solar cell in Amperes

R_S=Series resistance in ohm

For the diode equation, Current flowing through the diode is,

$$I_D = I_0\{exp[\frac{qv_j}{nkT}]-1\} \quad (3)$$

Where,

I_0 =Reverse saturation current in amperes

N=diodes identity factor

Q=elementary charge

K=Boltzmann's constant

T=absolute temperature

By ohms low, Current in shunt resistance is,

$$I_{SH} = \frac{V_j}{R_{SH}} \quad (4)$$

Put all values in equation (1) for generation of characteristics equation for solar array,

$$I = I_L - I_0\{exp(\frac{q(V+IR_S)}{nkT}) - 1\} - \frac{V+IR_{SH}}{R_{SH}} \quad (5)$$

Above equation shows obtained characteristics equation for PV array.

B. PULSE WIDTH MODULATION TOPOLOGY

The carrier- based correction technique employed in PWM topology, which is also effective to reduce harmonic distortion, is used to construct the switching sequence. To accomplish the requisite twenty-five levels, the PWM controlled approach uses a sinusoidal signal as a reference with twenty-four reference triangular waves. For proposed modal, this approach is implemented in MATLAB/Simulink. Figure 4 depicts the switching pattern for switch k1. Where the constant PWM approach is used to construct the switching sequence for switch k1. The switching sequence for switch K1 is produced using sine and saw-tooth waveforms. (Figure 3.4)

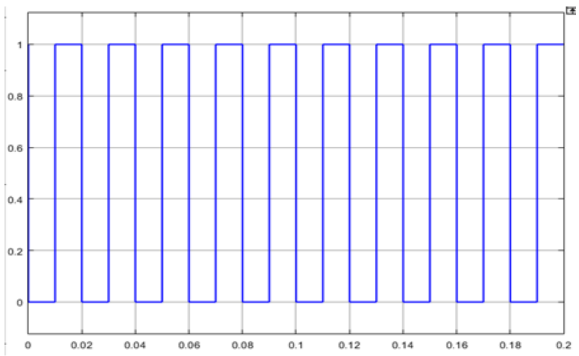

Fig 3.4. Generated Pulse for K_1 Switch.

C.THD CALCULATION

Harmonics records up to 13th harmonics and after that values become minimum nearly equal to zero. To calculate harmonics theoretically amplitude of each harmonics represents in table no 3.1.

Table 3.1. Harmonics Vs Amplitude of Proposed Modal

Sr.no	Harmonics no.	Amplitude (V)
1	1	100
2	3	1.8
3	5	0.6
4	7	0.7
5	9	0.6
6	11	0.3
7	13	0.59

Put all recorded values in THD equation, as follows

$$THD=\frac{\sqrt{0.1^2+1.8^2+0.6^2+0.7^2+0.6^2+0.3^2+0.59^2}}{100}$$

THD=3.36%

The obtained THD is 3.36 percent theoretically. he fast Fourier transform (FFT Analysis) is used to calculate harmonic distortion in the Simulink model. FFT analysis is used to convert signals from the time domain to the frequency domain. The magnitude vs. frequency plot of the proposed modal signals is given by the FFT spectrum.

4.RESULT

Figure 4.1 illustrates the implementation of the 25-level cascaded hybrid multilevel inverter with standalone PV array and switches using MATLAB/Simulation. Proposed mode consists of twelve hybrid bridges, each with four switches that are IGBTs, forty-eight IGBTs, and twelve standalone PV arrays to meet load demand. In MATLAB/Simulink, IGBT is utilized as a switch. The simulated waveforms in figure 4.2 are displayed. There are 25 levels of output ac voltage in the simulated waveform. Figure 4.3. Shows 25-level output with of HMLI with t=0.2sec

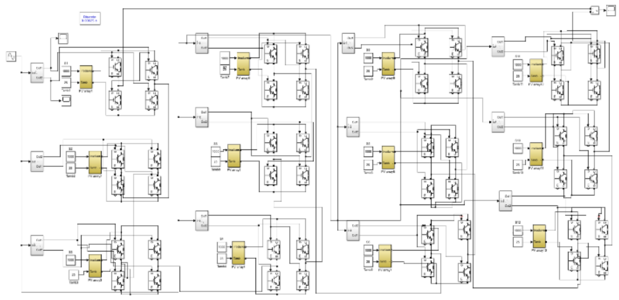

Fig 4.1. MATLAB Modal of 25-Level HMLI

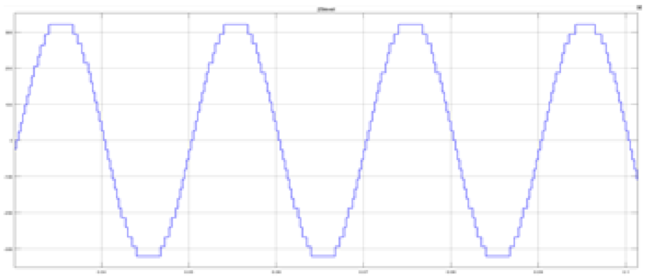

Fig 4.2. 25-Level HMLI

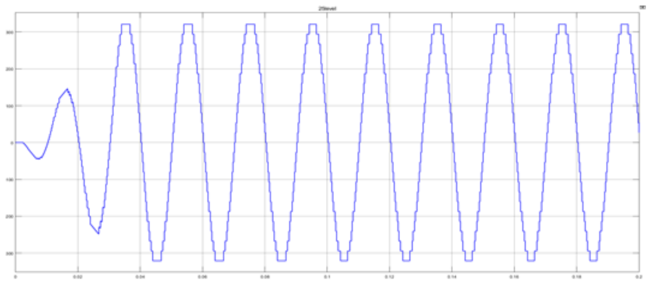

Fig 4.3. 25-Level Output of HMLI with t=0.2sec

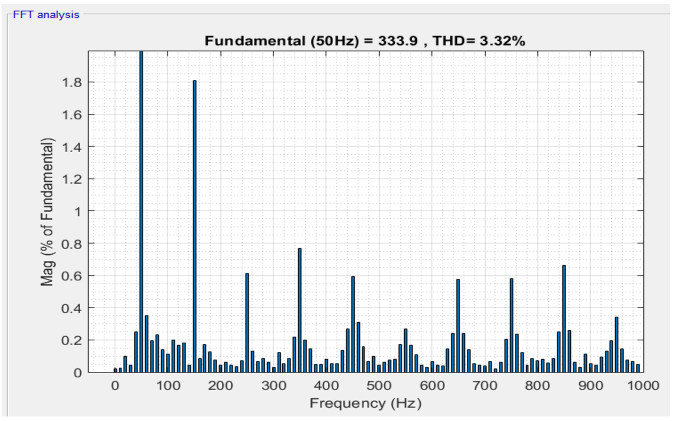

Fig 4.4. FFT Spectrum of 25-Level HMLI

Figure 4.4 of the simulation results displays the THD values in the proposed modal, which are 3.32 percent. To calculate THD, a fast Fourier transform analysis is used. FFT analysis is carried out in MATLAB/Simulink. The time domain signal is converted to the frequency domain during FFT analysis. The response signal magnitude versus frequency relationship is presented on a graph.

5. COMPARISION WITH REFERENCE MODAL

Eight PV panels and a topology with a 17-level inverter were suggested by Muhammad Hamza Shahbaz et al. [10]. The reference model, which included four power electronic switches in eight bridges, produced a THD of 6.69%. As a result, this paper has produced cutting-edge and highly important results that are lacking in the body of existing knowledge. Table 3 provides a comprehensive comparison. Our primary contribution is the use of a H-bridge inverter to produce 25 levels of voltage output, and we have integrated this HMLI with a PV array rather than DC supply. Only 17 levels were reached in the conventional model, which has a higher THD and lower dependability than the suggested approach.

Table 5.1 Comparison with a Reference Model

Sr, no.	Parameters	Reference model	Proposed model
1	Number of Output Level	17	25
2	Number of H-Bridges	8	12
3	Number of Switches	32	48
4	Total Harmonic Distortion	6.9%	3.36%

6 CONCLUSIONS

A Twenty-Five-Stage H-bridge multilevel inverter model that integrates solar PV is developed in this paper for use in high power applications. The suggested model uses twelve independent PV arrays rather than dc sources to meet load requirements. For output, a cascading arrangement is used. It uses a PWM controlled technique. Using MATLAB/Simulink, the proposed model's implementation is simulated. Results indicate that with high power, THD is almost is very low i.e. 3.36 percent (As Per IEEE Standards).

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