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Multilevel Inverter For Solar Power Applications

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***Abstract*- Multilevel voltage source inverters offer several advantages compared to their conventional counterparts. Synthesizing the AC output terminal voltage from several levels of voltages, staircase waveforms can be produced, which approach the sinusoidal waveform with low harmonic distortion, thus reducing the filter requirements. By increasing the level of the inverter we can get several advantages: get a good voltage wave form, Very low THD, reduced volume and cost. The need of several sources on the DC side of the converter makes multilevel technology attractive for photovoltaic applications. This paper provides an overview of a multilevel inverter topology and investigates their suitability for single-phase photovoltaic systems. A simulation model is based on MATLAB/SIMULINK is developed. An experimental 40W prototype inverter is built and tested. The results experimentally validate the proposed PWM based three H-bridge 27 level cascaded multilevel inverter**.

***Index Terms*—Cascaded H-bridge multilevel inverter, Dc link voltage, Total Harmonic distortion, Metal Oxide Semiconductor Field Effect Transistor, Insulated Gate Bipolar Transistor, Flexible AC Transmission System.**

I. INTRODUCTION

Multilevel converter technology is based on the synthesis of the AC voltage from several different voltage levels on the DC bus. As the number of voltage levels on the DC side increases, the synthesized output waveform adds more steps, producing a staircase wave which approaches the sinusoidal wave with minimum harmonic distortion [9]. Multilevel converters are particularly interesting for high power applications such as FACTS since the need of filters is reduced and the efficiency is high because all devices switch at fundamental frequency [10], [11]. In low power applications where switching frequencies are not as restricted as in high power applications various control methods such as multicarrier pulse width modulation or multiple hysteresis band control methods can be used to further reduce harmonics in the stepped waveforms [12], [13]. Multilevel converter topologies are especially suitable for PV applications since due to the modular structure of PV arrays different DC voltage levels can easily be provided. A multilevel converter not only achieves low power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application.

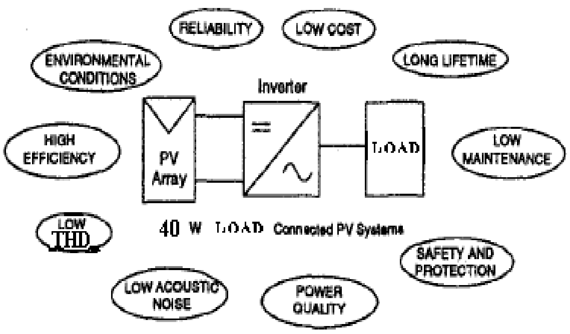

Figure1: Advantages of 27-level multilevel H-bridges inverter

Moreover the stage with higher DC link voltage has less switching frequency and therefore reduced switching losses. They also allow combining different types of switches to optimize the inverter efficiency .The new hybrid multilevel inverter consists of full bridge modules which have the relationship of 1v, 3v, 9v…..3s-1v for dc link Voltage .The output waveform has 27 levels, ± 13, ± 12, ±11, ±10, ± 9, ±8, ±7, ±6, ± 5, ±4, ±3, ± 2, ±1,0.

Inverter generates 3^s different voltage levels (e.g.an inverter with s=3 cells can generate 3^3=27 different voltage level).The basic hybrid multilevel inverter structure for single phase is illustrated in Fig 1.This multilevel inverter is made up of a set of series connected cells. Each cell consists of a 4-switch H-bridge voltage source inverter. The output inverter voltage is obtained by summing the cell contributions.

In conventional method, low level inverter is used. Better sinusoidal output was not obtained which is the drawback of the conventional system and the harmonics was high. So increase the levels of the inverter to get high resolution, hence the output wave form is mostly sinusoidal wave form.

The common function of multilevel inverter is to synthesize a desired voltage from several separate DC sources [10]. Each source is connected to a single phase full bridge inverter. Each inverter is capable of generating three different output voltages, **+V_{dc}**, 0 and **- V_{dc}.**

II. MODELING OF MULTILEVEL NEW HYBRID INVERTER

For each full bridge inverter the output voltage is given by $\mathbf{V_{0i} = V_{dc}(S_{1i}-S_{2i})}$

And the input dc current is $\mathbf{I_{dci} = I_a(S_{1i}-S_{2i})}$

i =1,2,3…(number of full bridge inverters employed). I_a is the output current of the new hybrid inverter. S_{1i} *and* S_{2i} is the upper switch of each full bridge inverter. Now the output voltage of each phase of the multilevel new hybrid inverter is given by

$$V_{on} = \sum_{i=1}^{n} V_{0i}$$

III. PROPOSED THREE H-BRIDGE 27- LEVEL MULTILEVEL INVERTER

The topology of the proposed Dc–Ac H-bridge multilevel inverter is shown in Figure.3. The inverter uses a standard three-leg and an H-bridge with its dc source in series with each phase leg.

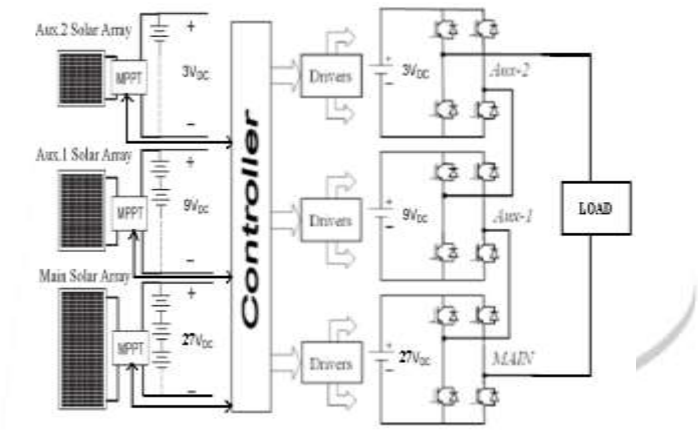

Figure 2: Single phase proposed dc–ac three H-bridge 27 levels multi level inverter.

In this proposed method of the inverter, has three input stages, all the three stages are a like in the construction module. All the modules are connected as new hybrid with each module having power switches. The power switches may be IGBT, MOSFET or any other power devices. The MOSFET's are used in this system. The power switches are operated in switching mode such that any two switches are in operating conditions at a time and other two remain in open condition. The switching is as S11=S13and S12= S14 this method is adopted to protect the circuit from short circuiting. The number of levels is increased by connecting maximum number of modules.

IV. NEW HYBRID INVERTER SWITCHING

Output voltages and switching states for the new hybrid inverter, S=3

Vdc \ Vout	-13V	-12V	-11V	-10V	-9V	-8V	-7V	-6V	-5V	-4V	-3V	-2V	-1V	0V	1V	2V	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V	13V
1V	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P	N	0	P
3V	N	N	N	0	0	0	P	P	P	N	N	N	0	0	0	P	P	P	N	N	N	0	0	0	P	P	P
9V	N	N	N	N	N	N	N	N	N	0	0	0	0	0	0	0	0	0	P	P	P	P	P	P	P	P	P

V. SWITCHING STATE FOR 180º MODE OF OPERATION

S.NO	First 90° mode of operation switching pattern	For next 90° mode of operation switching pattern
1	S1,S4,S5,S6,S9,S10 (Vo=3v)	S1,S4,S5,S8,S9,S12
2	S2,S3,S5,S8,S9,S10 (Vo=6v)	S1,S2,S5,S8,S9,S12
3	S1,S2,S5,S8,S9,S10 (Vo=9v)	S2,S3,S5,S8,S9,S12
4	S1,S4,S5,S8,S9,S10 (Vo=12v)	S1,S4,S5,S6,S9,S12
5	S2,S3,S6,S7,S9,S12 (Vo=15v)	S1,S2,S5,S6,S9,S12
6	S1,S2,S6,S7,S9,S12 (Vo=18v)	S2,S3,S5,S6,S9,S12
7	S1,S4,S6,S7,S9,S12 (Vo=21v)	S1,S4,S6,S7,S9,S12
8	S2,S3,S5,S6,S9,S12 (Vo=24v)	S1,S2,S6,S7,S9,S12
9	S1,S2,S5,S6,S9,S12 (Vo=27v)	S2,S3,S6,S7,S9,S12
10	S1,S4,S5,S6,S9,S12 (Vo=30v)	S1,S4,S5,S8,S9,S10
11	S2,S3,S5,S8,S9,S12 (Vo=33v)	S1,S2,S5,S8,S9,S10
12	S1,S2,S5,S8,S9,S12 (Vo=36v)	S2,S3,S5,S8,S9,S10
13	S1,S4,S5,S8,S9,S12 (Vo=39v)	S1,S4,S5,S6,S9,S10

Three DC voltage sources with a ratio of $V_1:V_2:V_3=1:3:9$ are used in the proposed system to obtain a 27-level inverter[4].

The ratio of three separate DC voltage source is follows

$$V_1:V_2:V_3=1:3:9$$

The output voltage of each H bridge unit is as follows

$$V_{ab} = \begin{cases} +1V_1 & S_1,S_4 \quad ON \\ 0\ V_1 & S_1,S_3 \quad ON \\ -1V_1 & S_2,S_3 \quad ON \end{cases}$$

$$V_{bc} = \begin{cases} +3\ V_2 & S_5,S_8 \quad ON \\ 0\ \ V_2 & S_5,S_7 \quad ON \\ \text{-3}\ \ V_2 & S_7,S_6 \quad ON \end{cases}$$

$$V_{ca} = \begin{cases} +9\ V_3 & S_9,S_{12} \quad ON \\ 0\ \ V_3 & S_9,S_{11} \quad ON \\ \text{-9}\ \ V_3 & S_{10},S_{11} \quad ON \end{cases}$$

The output voltage (V_{an}) of the cascade inverter is $V_{an} = V_{ab} + V_{bc} + V_{ca}$

By using Three H-bridge module fed with separate dc voltage sources with the ratio of 1:3:9 and by controlling the switching of the inverter modules an output of 27 voltage levels can be generated. The output voltage ranges from -13 V_{dc} to +13V_{dc} .

A. Inverter resolution

The more asymmetrical configuration, the higher the resolution. The recognized number of cells, one can change the type of the cells and their supply voltages. To obtain a structure that generates identical levels, the supply voltages must examine the single-phase uniformity provision

$$\Delta \mathrm{U}_{\mathrm{k}} \leq \Delta U_{k+1} \leq \Delta U_{1} + \sum_{j=1}^{k} \left(n_{j}-1\right).\Delta U_{j}$$

Where U_k and n_j are the step and the quantity of level of the k_{th} cell and where U_1 is also the step of the resulting inverter. This condition is a function of the number of levels and of the steps of the combined cells. For the proposed structure, with one H-bridge in series the number of levels can go up to 27.

B. Inverter efficiency

The efficiency of a hybrid inverter is higher than a conventional inverter, for the applications where the switching losses are bigger. The efficiency of the proposed structure is between the efficiency of the ideal hybrid inverter and a conventional multilevel inverter fully supplied with dc-dc converters. At the same time, it is an attractive solution to get a large number of levels together with a good efficiency.

VI. SIMULATION RESULTS

The proposed cascaded multilevel inverter with varying DC input has been simulated using MATLAB/Simulink software tool under different loading condition and performance analysis had been made based on the THD values at different load condition.

Parameters	Value
Phase	Single
Frequency	50HZ
V_{dc1}	3
V_{dc2}	9
V_{dc3}	27
Power Rating	1KW

Table 2 .Parameters of proposed cascade inverter

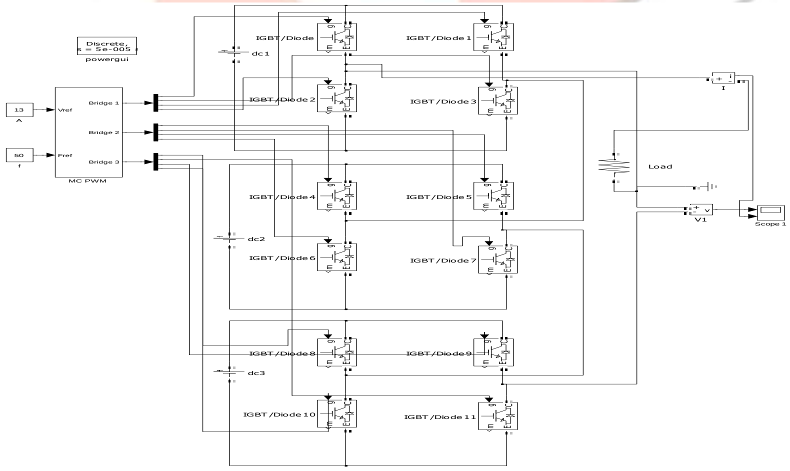

Figure.3: simulation for single phase 27 level inverter

The simulink block of 27-level Multi level inverter is shown in figure, consists of DC source, inverter and voltage, current measurement. The gate pulse of inverter switches are controlled by sinusoidal pulse width modulation which in turn controls the switch. The simulation model for individual phase voltages for a three phase cascaded multilevel inverter with R load is shown in Figure.3.Figure .4. represents the Voltage modulation cycle of the single phase cascaded multilevel inverter when running a R load of about 1kW. Figure.5 holds the output voltage and current with R load .Figure 6 holds the THD analysis for output voltage. Figure 7 holds the THD analysis for output current.

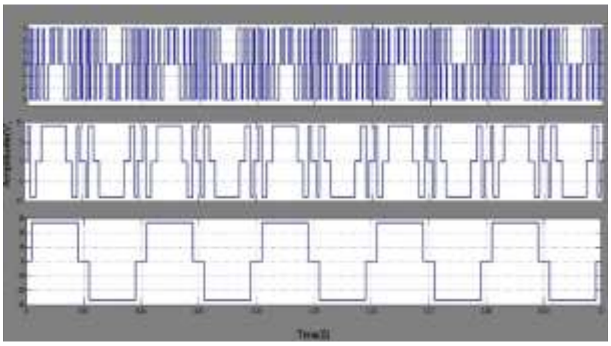

Figure 4.Voltage Modulation Cycle

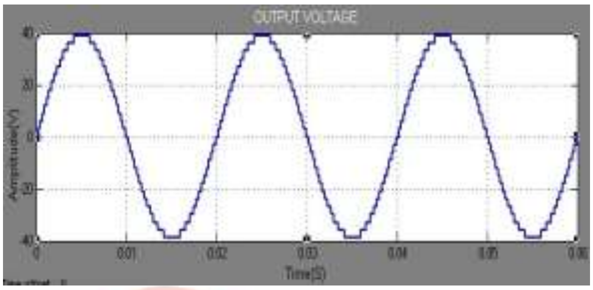

Figure 5. Output voltage with R load

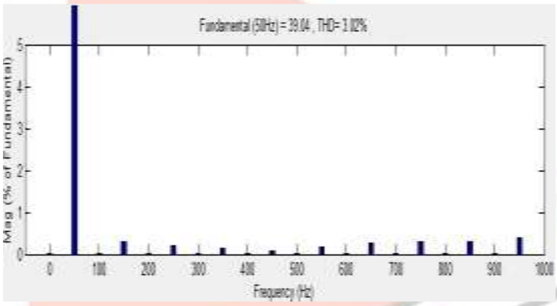

Figure 6. THD analysis of output voltage with R load

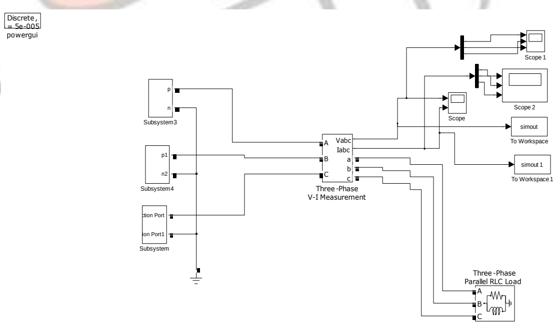

Figure 7.Simulation for three-phase 27 level multilevel inverter

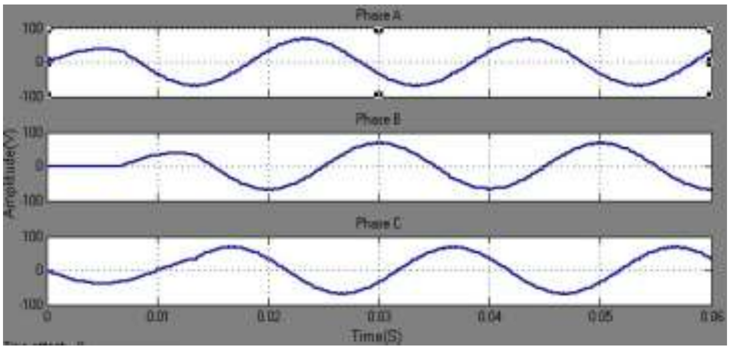

Figure 8.Individual Phase Voltage

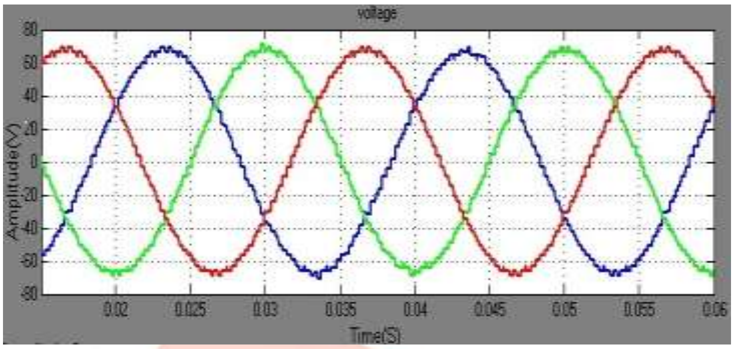

Figure 9.Line –to –Line Voltage

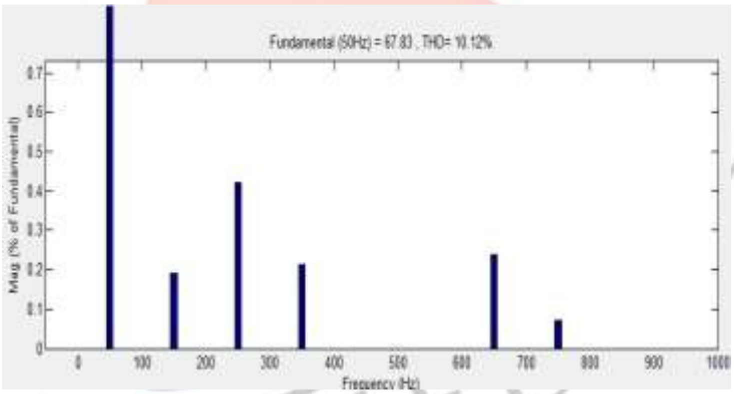

Figure 10.THD analysis for Line Voltage

VII. CONCLUSION

An improved new hybrid 27 level multilevel inverter structure is proposed. Basic new hybrid inverter scheme is to get the better sinusoidal output compared with low level inverters. The asymmetrical multilevel inverter is used to obtain a high resolution. By this method decrease the input voltage and get better efficiency in a 27 level multi level inverter structure. As per the design of the proposed 27 level multilevel inverter, the total harmonic distortion is dramatically reduced to 4.84%.The asymmetrical hybrid technique is used to improve the level of inverter and extends the design flexibility and reduces the harmonics.

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