Ashwani Singh, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 11, Issue 6, (Series-V) June 2021, pp. 09-13

RESEARCH ARTICLE OPEN ACCESS

Design of a 27 Level Hybrid Inverter for Solar Photovoltaic Application

Ashwani Singh
Mtech scholar, Vishwavidyalaya Engineering College
Lakhanpur

Mr Swatantra Singh Verma
Assistant Proffessor, Vishwavidyalaya Engineering College
Lakhanpur

ABSTRACT:
As compared with the conventional inverters, a multilevel inverter has many advantages like low voltage THD and current THD. A stepped ac voltage waveform is obtained in an H bridge inverter connected in cascade. As the voltage output of the multilevel inverter is a stepped wave that resembles that of a purely sinusoidal ac voltage, the need for filters is reduced. Along with that due to the reduction in filters requirement the cost and volume of the overall system are also reduced. In a multilevel inverter in every stage dc source is connected so this technology proves to be attractive for the application of solar photovoltaic panels as solar photovoltaic panels also generated electricity in stages. In this paper, a 27 level inverter is designed in MATLAB Simulink. The validity of the design is illustrated from its total harmonic distortion in the results.

Keywords: 27 level inverter, cascaded inverter, total harmonic distortion, voltage THD, current THD.

Date of Submission: 15-06-2021 Date of Acceptance: 30-06-2021

I. INTRODUCTION

Multilevel inverter technology is based on the fact that if many H- Bridge inverters are connected in cascade then by appropriate switching of the switches stepped ac voltage can be obtained. If the number of H- bridges in the cascaded multilevel inverter is increased then several steps in the output voltage also get increased and the output voltage comes near to the pure sinusoidal ac voltage. The multilevel inverter is utilized in high power applications such as hybrid solar systems and FACTS. As the number of voltage levels is increased the requirement of filters is reduced, along with that as the harmonics are also reduced the overall efficiency of the system also becomes high. In low power applications, the switching frequency is not restricted so harmonic content can be reduced by using control methods such as multicarrier pulse width modulation; multiple hysteresis band control, etc. due to the cell structure of the solar photovoltaic system multilevel inverter is very much suitable. In a solar PV system, each solar array provides different dc voltage levels. This voltage source can be connected to different H- Bridge so that different voltage stages can be obtained. Thus the use of multilevel inverter can be proved to be very useful in solar applications or fuel cell applications. Various advantages of a multilevel inverter are:

1. It increases the reliability of the system.
2. Reduces the requirement of filters.
3. Reduces the switching losses.
4. Improves the power quality.
5. Low maintenance requirement.
6. It has high efficiency.
7. Reduces the total harmonic distortion.

The single-phase structure of a multilevel inverter is as shown in figure 1.

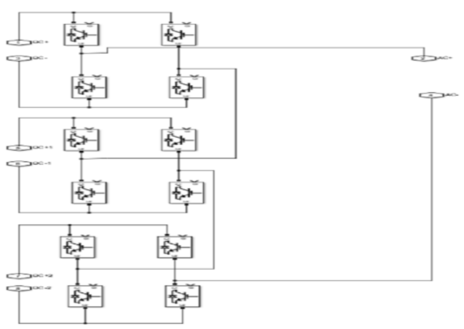

Fig 1 Cascaded multilevel inverter, single-phase structure

Dc link voltage present in the multilevel inverter has a low switching frequency and thus has less switching loss. Thus it allows combining different types of switches to increase the efficiency of the inverter. The inverter proposed has three sets of the dc-link voltage of value ±1 V, ±3 V, ± 9 V. From the three sets of dc voltage 27 levels of voltage can be obtained at the output stage by the various combination of the switches. From the 27 levels of output voltage stepped output waveform which is nearly a sinusoidal voltage can be obtained. Three single-stage inverters are connected to produce a stepped output voltage is obtained at the output.

II. MODELING OF 27 LEVEL MULTILEVEL INVERTER

Each block of the cascade multilevel inverter has a different voltage source. So by the combination of switches 27 different levels of voltage can be obtained. The internal circuit of 1st block is as shown in figure 2

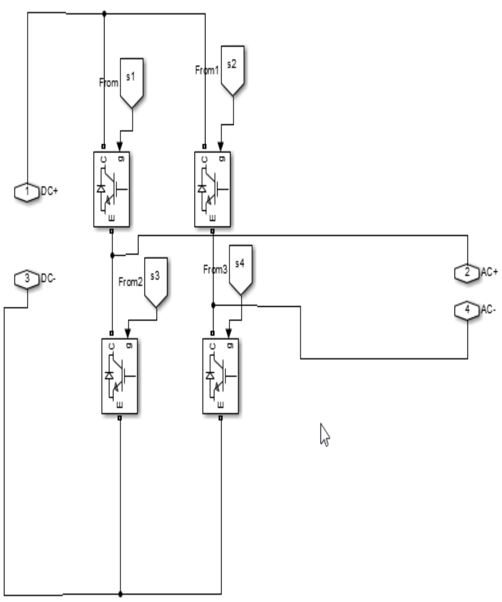

Fig 2 Internal circuit of 1st block.

The output of the 1st block is V_{dc} when S_1 and S_4 switch is turned on, it is $-V_{dc}$ when S_2 and S_3 switch is turned on and it is 0 volt when S2 and S4 switches are turned on. In a similar manner in the 2nd block and 3rd block also three voltages can be obtained by the combination of various switches. From three voltage combinations of each block total of $3^3 = 27$ voltages can be obtained at the output stage and by proper sequencing, the output voltage will be a stepped voltage whose shape will be similar to the desired sinusoidal voltage. The complete simulation is done in MATLAB Simulink and it is shown in figure 3.

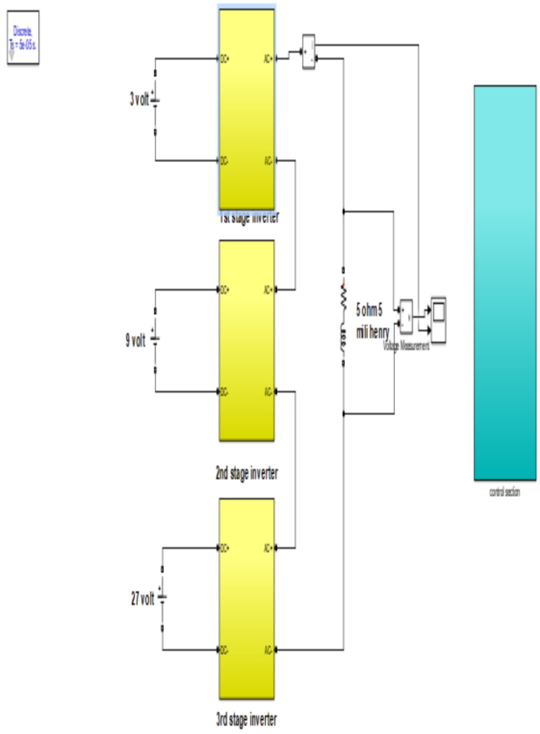

Fig 3 Simulation model of a 27 level inverter

As seen from the model it consists of three-stage inverters connected in cascade. The 1st stage of the inverter is connected with a 3-volt source, the second stage of the inverter is connected with a 9-volt source and the 3rd stage is connected with a 27-volt source. The output of the inverter is connected with a load having a resistance of 5 ohms and an inductance of 5 milli henry. It is assumed that the output of the solar panel is a constant dc source and each panel is connected to a different panel having 3 volts, 9 volts, and 27-volt output. To supply the ac load these dc voltages are to be converted into an ac source so it can be achieved by the inverter.

III. SWITCHING TECHNIQUE OF THE PROPOSED MODEL

A combination of different switches will give out different values of output at the ac side. The output voltages that can be obtained at the ac side are -39 to 39 volt in an interval of 3 volts. The switching table for different voltage output at the ac side is shown in table 1.

Output voltage	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12
-39	0	1	1	0	0	1	1	0	0	1	1	0
-36	0	0	1	1	0	1	1	0	0	1	1	0
-33	1	0	0	1	0	1	1	0	0	1	1	0
-30	0	1	1	0	0	0	1	1	0	1	1	0
-27	0	0	1	1	0	0	1	1	0	1	1	0
-24	1	0	0	1	0	0	1	1	0	1	1	0
-21	0	1	1	0	1	0	0	1	0	1	1	0
-18	0	0	1	1	1	0	0	1	0	1	1	0
-15	1	0	0	1	1	0	0	1	0	1	1	0
-12	0	1	1	0	0	1	1	0	0	0	1	1
-9	0	0	1	1	0	1	1	0	0	0	1	1
-6	1	0	0	1	0	1	1	0	0	0	1	1
-3	0	1	1	0	0	0	1	1	0	0	1	1
0	0	0	1	1	0	0	1	1	0	0	1	1
3	1	0	0	1	0	0	1	1	0	0	1	1
6	0	1	1	0	1	0	0	1	0	0	1	1
9	0	0	1	1	1	0	0	1	0	0	1	1
12	1	0	0	1	1	0	0	1	0	0	1	1
15	0	1	1	0	0	1	1	0	1	0	0	1
18	0	0	1	1	0	1	1	0	1	0	0	1
21	1	0	0	1	0	1	1	0	1	0	0	1
24	0	1	1	0	0	0	1	1	1	0	0	1
27	0	0	1	1	0	0	1	1	1	0	0	1
30	1	0	0	1	0	0	1	1	1	0	0	1
33	0	1	1	0	1	0	0	1	1	0	0	1
36	0	0	1	1	1	0	0	1	1	0	0	1
39	1	0	0	1	1	0	0	1	1	0	0	1

Table 1 switching table of the model

To illustrate the table let us take a case of getting 39 volts at the output. To obtain so positive voltage of all the three stages must be added that is 3+9+27=39 volt. This can be achieved when switches s1 and s4 of the 1st stage, s5 and s8 of the second stage, and s9 and s12 of the third stage are triggered. Because of this pattern, the above switching pattern is created.

IV. CONTROL TECHNIQUE OF THE PROPOSED MODEL

The discrete control technique is implemented to control the inverter to obtain the output voltage with minimum total harmonic distortion. A reference voltage of 39-volt amplitude and frequency equal to desired 50 Hz is utilized. The reference voltage is again divided into a different range of voltages in steps of three and 27 discrete voltages are obtained. The switching signals are generated as per the required combination of these discrete voltages for example the switch s1 of the1st stage is turned on when the discrete reference voltage value is either -33,-24, -15, -6, 3,12,21,30, or 39. So the switching of the switch S1 is done accordingly. Similarly, switching signals of all the switches are generated as per the switching scheme of table 1.

V. SIMULATION RESULT

The output voltage of the proposed model is as shown in figure 4 .

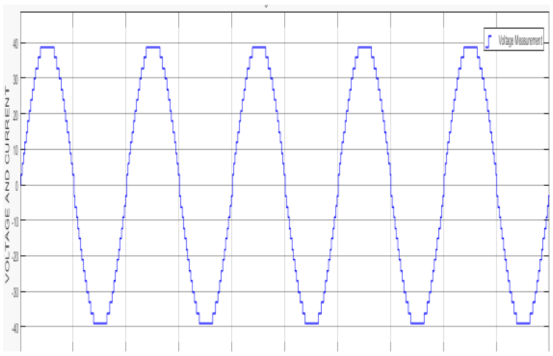

Figure 4 output voltage waveform

As can be seen in the figure the output voltage seems to be very near to the sinusoidal voltage of magnitude 39 volts.

The output current waveform of the proposed model modeled in MATLAB Simulink is as shown in figure 5.

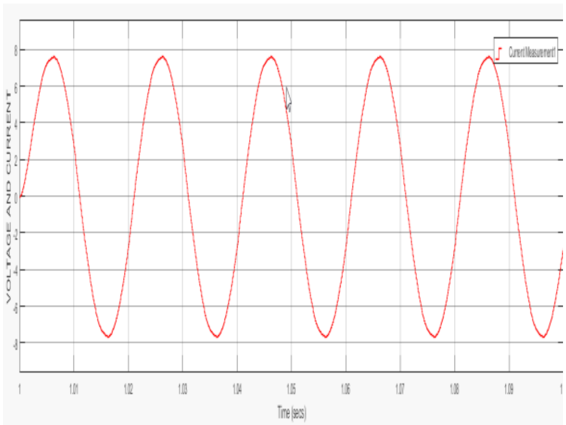

Figure 5 output current waveform

As seen the current waveform is nearly harmonic-free.

FFT analysis of voltage as well as the current waveform is also performed in MATLAB Simulink. FFT analysis of output voltage and current is shown in Figures 6 and 7.

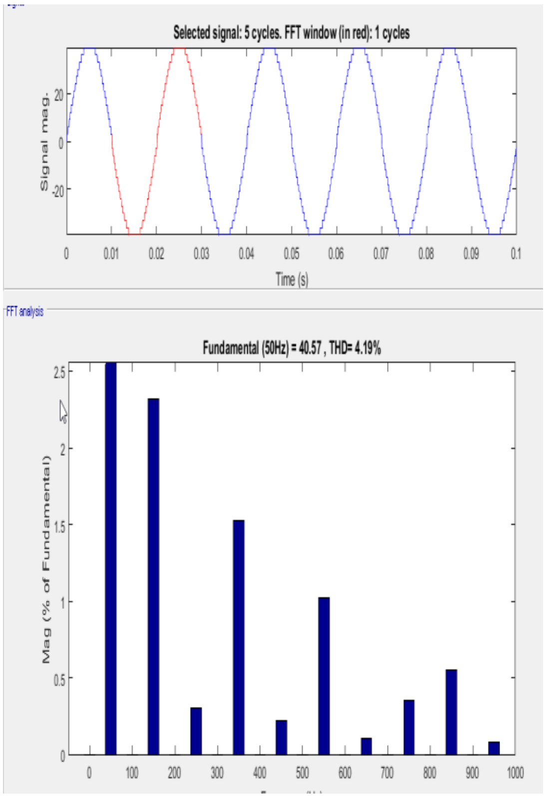

Fig 6 FFT analysis of output voltage

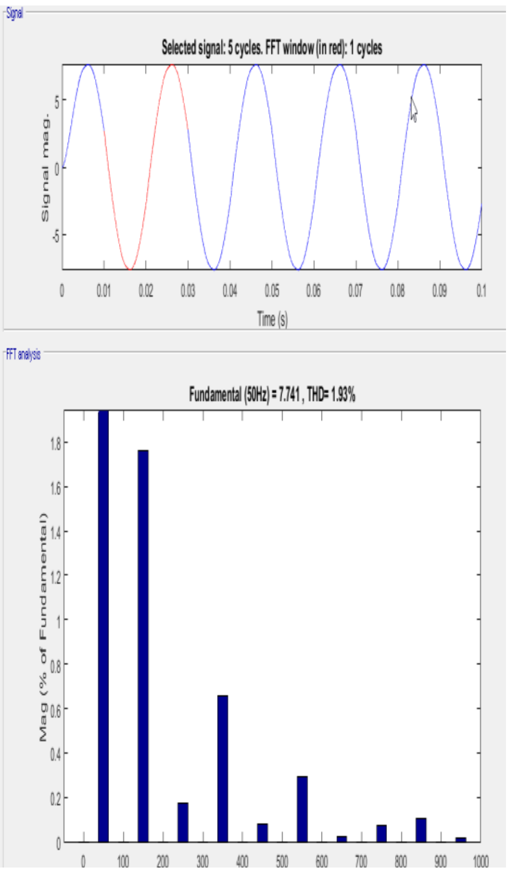

Fig 7 FFT analysis of output current

VI. CONCLUSION

There are several kinds of controlling techniques present in the literature such as sinusoidal pulse width modulation, space vector PWM, selective harmonic elimination, active harmonic elimination, and all of them can be utilized in the inverter control. In the proposed model controlling is done by discretization of the reference voltage and generating reference voltage by applying logic as per the switching table. From the result obtained it is very much clear that a very high-quality voltage and current waveform are obtained at the output terminal. Along with that, the total harmonic distortion in voltage waveform is only 4.19% and in current waveform, it is only1.93% which means the power quality at the output side is very good. Thus this topology of 27 levels hybrid multilevel inverter proves to be very efficient to be used along with solar PV panel to convert dc power to ac power.

REFERENCES

[1]. Sushree Smrutimayee Barah; Sasmita Behera, “An Optimize Configuration of H-Bridge Multilevel Inverter”, 1st International Conference on Power Electronics and Energy (ICPEE), 2-3 Jan. 2021

[2]. Kalpesh Y Rawal, V.J. Ravavara, “Novel Multilevel Inverter Design with Reduced Device Count”. International Conference on Current Trends towards Converging Technologies (ICCTCT), 1-3 March 2018

[3]. J. S. Lai and F. Z. Peng, ―Multilevel converters- A new breed of power converters,‖ IEEE Trans Ind. Appl., vol. 32, no. 3, pp. 36–44, May/Jun.1996.

[4]. K. M. Rahman, N. R. Patel, T. G. Ward, J. M. Nagashima, F.Caricchi,and F. Crescimbini, ―Application of direct-drive wheel motor for fuel cell electric and hybrid electric vehicle propulsion system,‖ IEEE Trans. Ind.Appl., vol. 42, no. 5, pp. 1185–1192, Sep/Oct. 2006.

[5]. J. S. Lai and F. Z. Peng, ―Multilevel converters- A new breed of power converters,‖ IEEE Transactions on Industry Applications, vol. 31, no.3, May./June 1997, pp. 509-517.

[6]. L. M. Tolbert, F. Z. Peng, T. G. Habetler,―Multilevel converters for large electric drives,‖ IEEE Transactions on Industry Applications, vol.35, no.1, Jan /Feb. 1999, pp. 36-44.

[7]. S. Onoda, A. Emadi, ―PSIM-based modeling of Auto motive power systems: conventional, electric, and hybrid electric vehicles IEEE Transactions on Vehicular

Technology, vol. 53, issue 2, 2004,pp. 390-395.

[8]. J. Rodríguez, J. Lai, and F. Peng, ―Multilevel inverters: a survey of topologies, controls and applications,‖ IEEE Transactions on Industry Applications, vol. 49, no. 4, Aug. 2002, pp. 724-738.

[9]. D.Zhong, B.Ozpineci, L. M. Tolbert, J. N. Chiasson, ―Inductor less DC-AC cascaded H-Bridge multilevel boost inverter for Electric/hybrid electric vehicle applications,‖ IEEE Industry Applications Conference, Sept. 2007, pp. 603-608.

[10]. D. Leuenberger and J. Biela, "PV-Module-Integrated AC Inverters (AC Modules) With Subpanel MPP Tracking," in *IEEE Transactions on Power Electronics*, vol. 32, no. 8, pp. 6105-6118.

[11]. M. Vasiladiotis and A. Rufer, "Analysis and Control of Modular Multilevel Converters With Integrated Battery Energy Storage," in *IEEE Transactions on Power Electronics*, vol. 30, no. 1, pp. 163-175, Jan. 2015, DOI: 10.1109/TPEL.2014.2303297.

[12]. H. Akagi, "Classification, terminology, and application of the modular multilevel cascade converter (MMCC)," *The 2010 International Power Electronics Conference - ECCE ASIA -*, Sapporo, Japan, 2010, pp. 508-515.

Ashwani Singh, et. al. “Design of a 27 Level Hybrid Inverter for Solar Photovoltaic Application.” *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (6), 2021, pp 09-13.