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DESIGN OF CASCADED SYMMETRIC MULTILEVEL INVERTER WITH REDUCED NUMBER OF SWITCHES FOR PV BASED GRID SYSTEM

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ABSTRACT
Solar energy is one of the renewable energy which is used to generate electricity with the help of PV arrays. DC-DC converter is used to step up the DC voltage from PV arrays and then it is connected to an inverter for AC applications. Conventional inverters have many issues like non sinusoidal output, high total harmonic distortion (THD), high switching stress and more number of switches. So multilevel inverter (MLI) have gained much importance over conventional inverters for high voltage and high power applications, due to the increased number of voltage levels producing less number of harmonics. In this paper, a cascaded asymmetric multilevel inverter is proposed which contains minimum number of switches and can be employed in AC applications using solar energy. The proposed topology consists of 25 output levels using 10 switches with near sinusoidal output, thereby reducing gate driver circuitry and optimizing circuit layout. Asymmetric multilevel inverter is more advantageous than symmetric multilevel inverter in obtaining more number of output levels using same number of voltage sources. The other advantages of proposed topology are low voltage stress and reduced THD. Simulation is carried out using MATLAB 2010a.

Keywords– *AC, DC, PV arrays, THD.*

I. INTRODUCTION
With the advancement in technologies, the most of world's needs depends on energy consumption. In a parallel definition it is considered to be the backbone of any country's economic growth. Hence forth energy development focuses on the maximum exploitation of sources available. It is well known fact about the distribution of energy supplements available across the globe. Due to discreet distribution of resources in atmosphere and also the consistency in supplies, multiple sources of resources exist to survive the needs of an area.
Depending on the availability and their nature the energy resources are classified in two broad categories:

a. Renewable Energy Resources
b. Non- Renewable Energy Resources.

Renewable energy resources are pure energy that results from the solar system's fundamental physics. These harvestable forces have existed for millennia, indeed from the beginning of the existence of the earth and the sun. It would be difficult to think of a scenario in which these sources of energy would ever fail to produce. Some of renewable energy sources are: sun energy, geo-thermal energy, wind, rain, tide etc.

A non-renewable resource (also known as a finite resource) does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human timeframes. An example is carbon-based, organically-derived fuel. The original organic material, with the aid of heat and pressure, becomes a fuel such as oil or gas. Fossil fuels (such as coal, petroleum, and natural gas), and certain aquifers are all examples of non-renewable resources.

Energy Generation
Energy generation came into existence with the discovery of electricity by Michael Faraday in 1820's and early 1830. The model developed was embedded for turning a copper coil at its own axis surrounded by a magnetic field. His methods are still the backbone of most of the power plants surviving in today's corporate sector. Since then numerous methods were discovered to commercially generate electricity. Effective methods to maximize the production of energy were practiced and improved over the era.

Today electricity is dominantly generated at a power station by electromechanical generators. These are driven by heat engines commonly fuelled by chemical combustion process or nuclear fission energy. Some other means of sources such as the kinetic energy of flowing water and wind are used for electro-mechanical generators. Other energy sources are solar photo voltaic and geo-thermal power. The common sources for electricity production for domestic and commercial purposes include:

a. Thermal energy.

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b. Hydro energy.
c. Nuclear energy.
d. Wind energy.
e. Solar energy.

These sources are prominently used as they are provides highest efficiency in spite of low high wastage of sources. Thermal power, hydro-electric and nuclear sources are considered to be non-renewable while solar and wind are renewable or non-ending resources.

Photovoltaic power control is one of the burning research fields these days. Researchers are round the clock to develop better solar cell materials and efficient control mechanisms. The challenge of the project and the new area of study were the motivations behind the project. This paper proposes a cascaded asymmetric multilevel inverter (MLI) which contains minimum number of switches and can be employed in AC applications using solar energy.

II. PROPOSED METHODOLOGY

Basic Cell of Proposed MLI

The proposed topology contains minimum number of switches for generating same output levels as compared to conventional MLI. The proposed MLI's basic cell generates5 output levels using 2 voltage sources (here the voltage sources represent stepped up DC-output voltage from PV arrays) and 5 switches with anti-parallel diodes. Figure 1 shows the arrangement of these switches, where S11, S12, S13, S14 are arranged same as conventional H-bridge while S15 is added to increase output level by selecting appropriate voltage source.

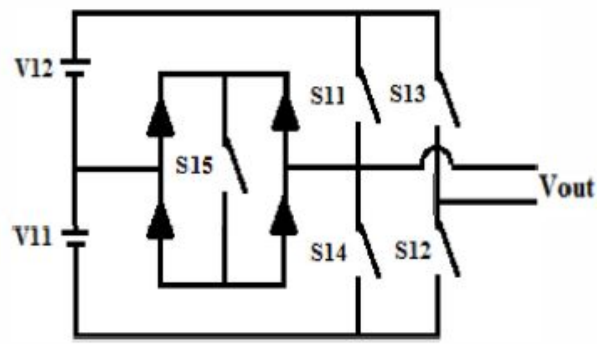

Figure 1: Basic cell of proposed MLI

Table 1: Switching states of basic cell

S11	S12	S13	S14	S15	Vol (o/p volt.)
1	1	0	0	0	Vll+Vl2
0	1	0	0	1	Vll
0	1	0	1	0	0
1	0	1	0	0	
0	0	1	0	1	-V12
0	0	1	1	0	- (Vll+Vl2)

Table 1 is shown above, regarding switching states of proposed MLI's basic cell where logic' l' is considered as 'ON' state and logic' 0' is considered as' OFF' state of switch. The basic cell consists of 2 voltage sources.

When the number of voltage sources in basic cell increase, then the number of output levels also increase. Table 2 illustrates relation between number of voltage sources in the basic cell and their respective number of output levels with corresponding number of switches.

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Table 2: Output levels for respective voltage sources in basic cell

No. of Voltage Sources	No. of Switches	No. of Output Levels
2	5	5
3	6	7
4	7	9
N	N+3	2N+1

Proposed Multilevel Inverter

The proposed topology of multilevel inverter is employed by cascaded arrangement of two basic cells. Here the Figure 2shows MLI where 25 output levels are obtained by using only10 switches. This arrangement can be further augmented by cascading 'P' number of basic cells in series. As the number of output levels is increased the output approaches close to sinusoidal waveform. This topology contains two cascaded basic cells. Each cell consists of two equal voltage sources. The voltage sources of second basic cell are in ratio of 1:5with respect to voltage sources of first basic cell. This topology helps to generate 25 output levels. This arrangement is defined as asymmetric MLI because of unequal voltage sources in two respective basic cells.

$$V11 = V12 = V_{dc} \qquad (1)$$
$$V21 = V22 = \frac{V_{dc}}{5} \qquad (2)$$
$$Vp1 = Vp2 = 5^{-(P-1)} \times V_{dc} \qquad (3)$$

If 'P' numbers of basic cells are cascaded for this particular topology then the output levels will be and valueof maximum voltage level is equal to $\frac{(V_{dc})(5-5^{-(P-1)})}{2}$.

Similarly if voltage sources of P cascaded cells are equal to the voltage sources of other basic cells that is in 1:1 ratio then the arrangement is defined as symmetric MLI.

$$V11 = V12 = V21 = V22 = VP1 = VP2 = V_{dc} \qquad (4)$$

This arrangement would generate 4P+1output levels and value of maximum output voltage level is $2P \times V_{dc}$.
The diodes are arranged as shown in the Figure 2. Total number of diodes for one basic cell is 4. So if 'P' cascaded basic cells are used then the total number of diodes required is given by 4P (anti-parallel diodes across switch are not considered). Here in proposed topology total 8 diodes are used.

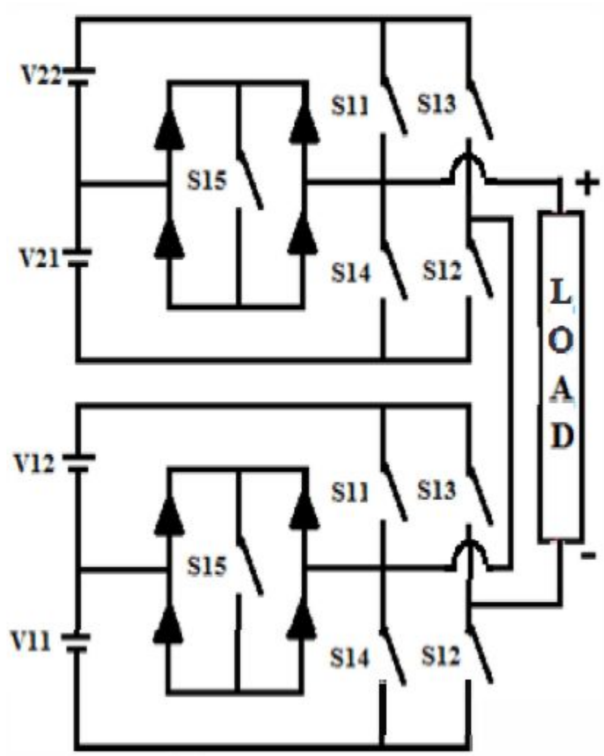


Figure 2: Proposed MLI with 10 switches

Operation of Proposed MLI

The operation of the proposed MLI is illustrated from the switching states in Table 3 below. The path of current flow is shown in Figure 3 and Figure 4, for positive level and negative level respectively. Zero output voltage is represented with two switching states. Switches S15 and S25 are select switches of two respective basic cells. These switches help to add number of output levels. When all basic cells are cascaded in series, output voltages of each basic cell are added together to achieve final output voltage across MLI.

$$V_{out} = V01 + V02 \qquad (5)$$

Table 3: Switching states of proposed MLI

LEVELS	S11	S12	S13	S14	S15	S21	S22	S23	S24	S25	Output voltage
1	0	1	0	0	0	0	1	0	0	0	0
	0	0	1	0	0	0	0	1	0	0	
2	0	1	0	0	0	0	1	0	0	1	V21
3	0	1	0	0	0	1	1	0	0	0	V21+V22
4	0	1	0	0	1	0	0	0	0	0	V11-V21-V22
5	0	1	0	0	1	0	0	0	0	1	V11-V22
6	0	1	0	0	1	0	1	0	0	0	V11
7	0	1	0	0	1	0	1	0	0	1	V11+V21
8	0	1	0	0	1	1	1	0	0	0	V11+V21

											+V22
9	1	1	0	0	0	0	0	0	0	0	V11+V12 -V21-V22
10	1	1	0	0	0	0	0	0	0	1	V11+ V12- V22
11	1	1	0	0	0	0	1	0	0	0	V11+V12
12	1	1	0	0	0	0	1	0	0	1	V11+V12 +V21
13	1	1	0	0	0	1	1	0	0	0	V11+V12 +V21+V2 2
14	1	1	0	0	0	0	1	0	0	1	-V22
15	1	1	0	0	0	0	1	0	0	0	-V21-V22
16	1	1	0	0	0	0	0	0	0	1	V21+ V22- V12
17	1	1	0	0	0	0	0	0	0	0	V21-V12
18	0	1	0	0	1	1	1	0	0	0	-V12
19	0	1	0	0	1	0	1	0	0	1	-V22-V12
20	0	1	0	0	1	0	1	0	0	0	- V21- V22-V12
21	0	1	0	0	1	0	0	0	0	1	V21+ V22-V11- V12
22	0	1	0	0	1	0	0	0	0	0	V21-V11- V12
23	0	1	0	0	0	1	1	0	0	0	- V11- V12
24	0	1	0	0	0	0	1	0	0	1	- V22-Vll- V12
25	0	1	0	0	0	0	1	0	0	0	- V21- V22-VII- VI2

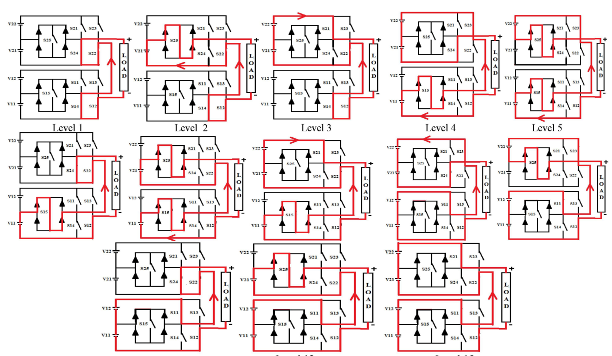
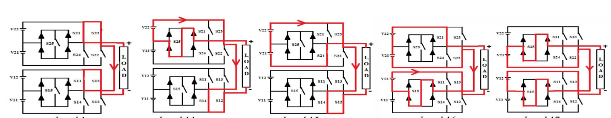


Figure 3: Current flow path during positive output levels



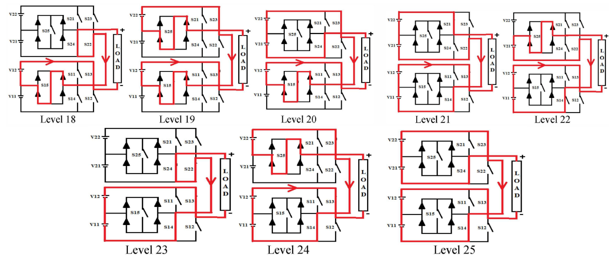


Figure 4: Current flow path during negative output levels

III. SIMULATION AND RESULTS

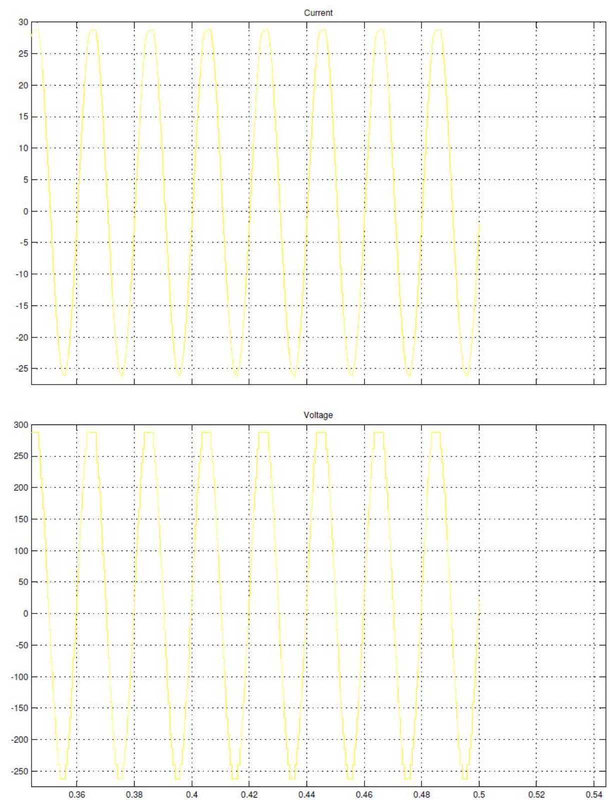


Figure 5: Output current and voltage

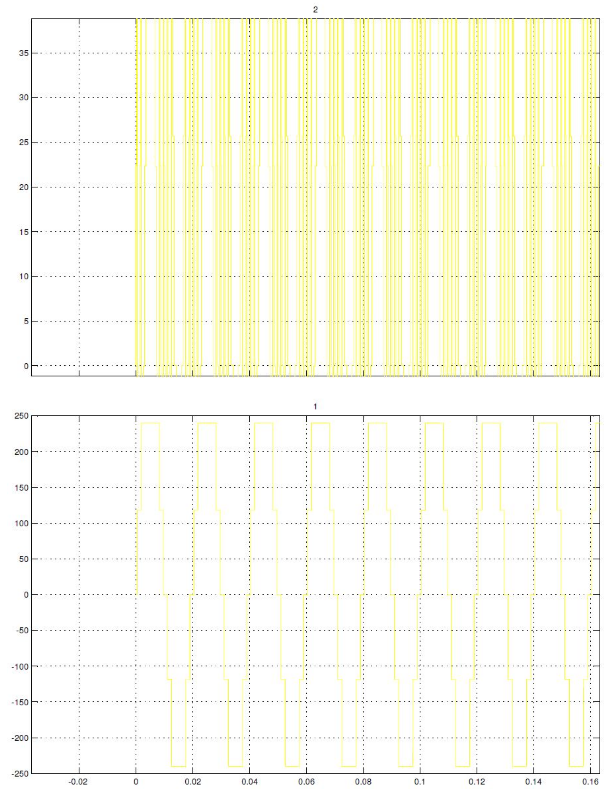


Figure 6: Output current and voltage

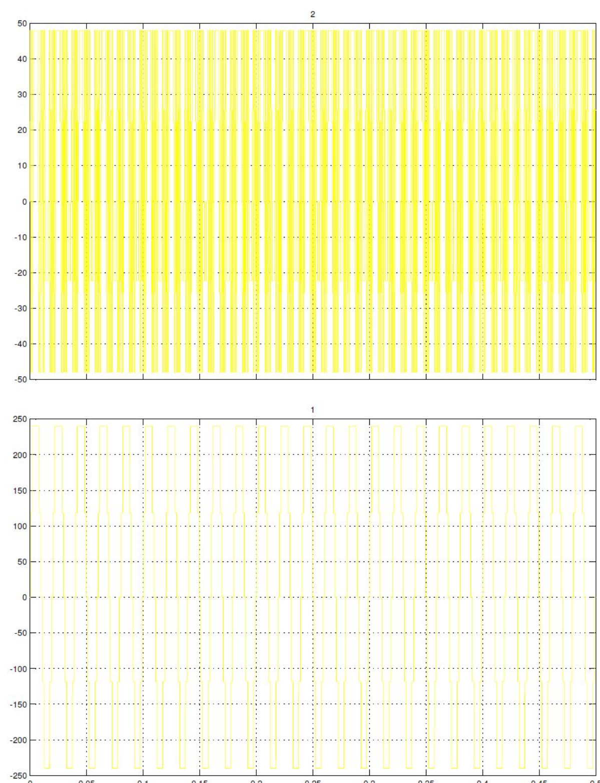


Figure 7: Output current and voltage

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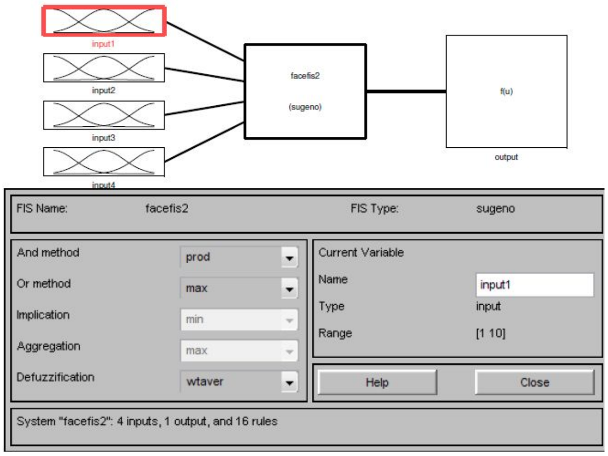

Figure 8: Fuzzy Inference System (FIS) system

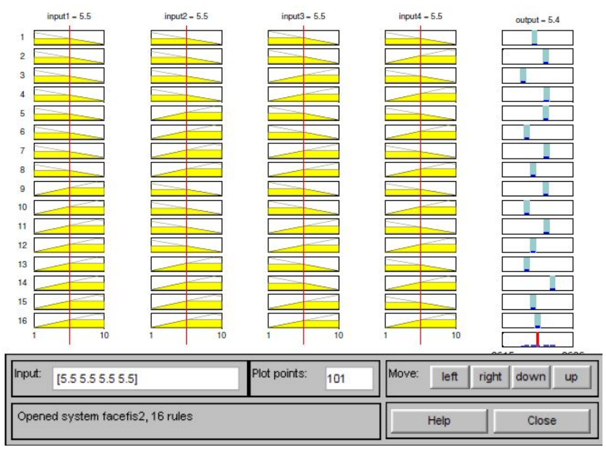

Figure 9: Fuzzy Rules

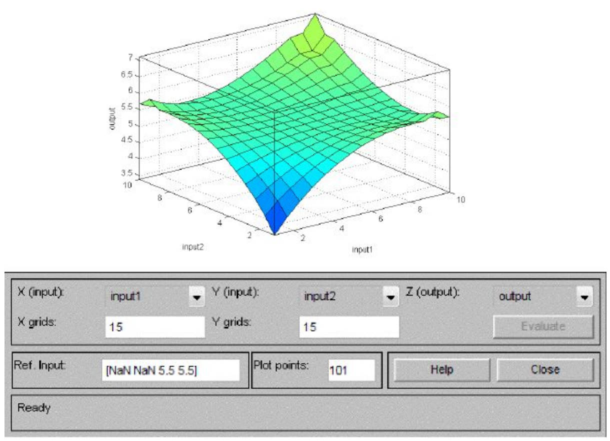

Figure 10: Fuzzy Inference System output surface

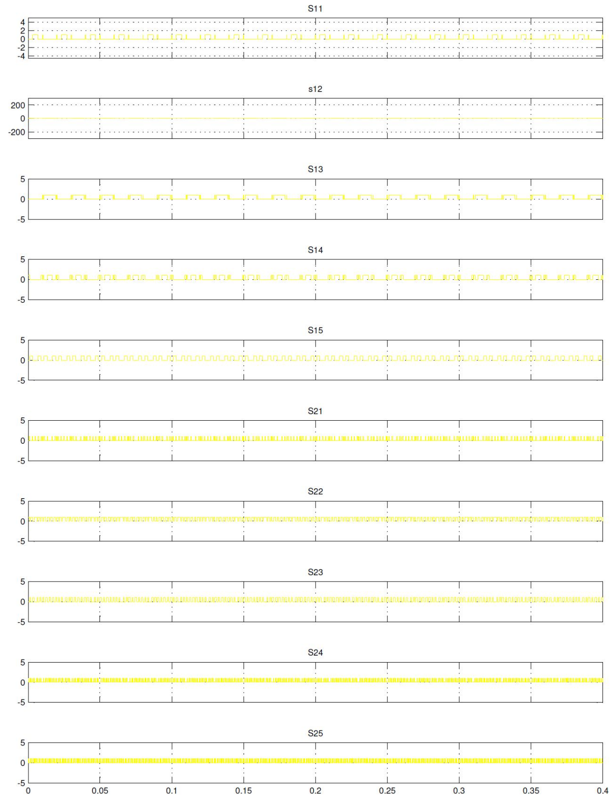

Figure 11: Output voltage of first and second basic cells

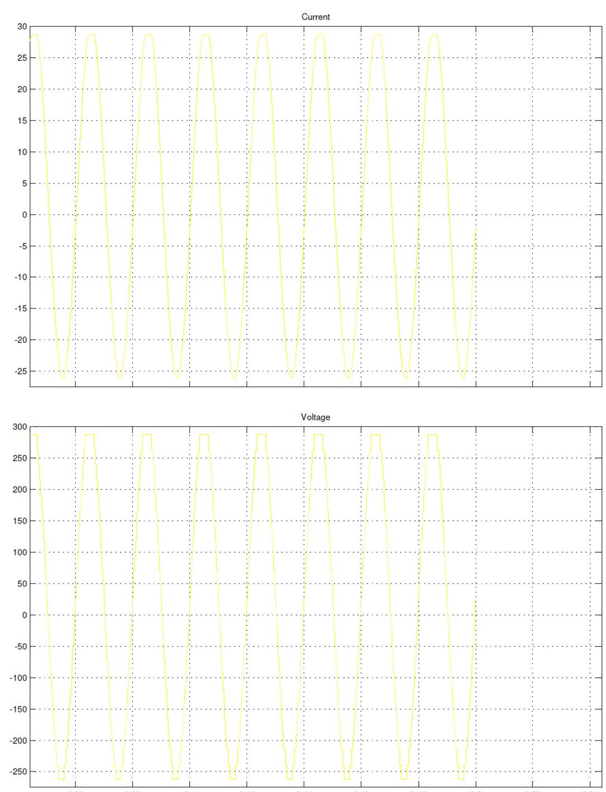

Figure 12: Output current and voltage

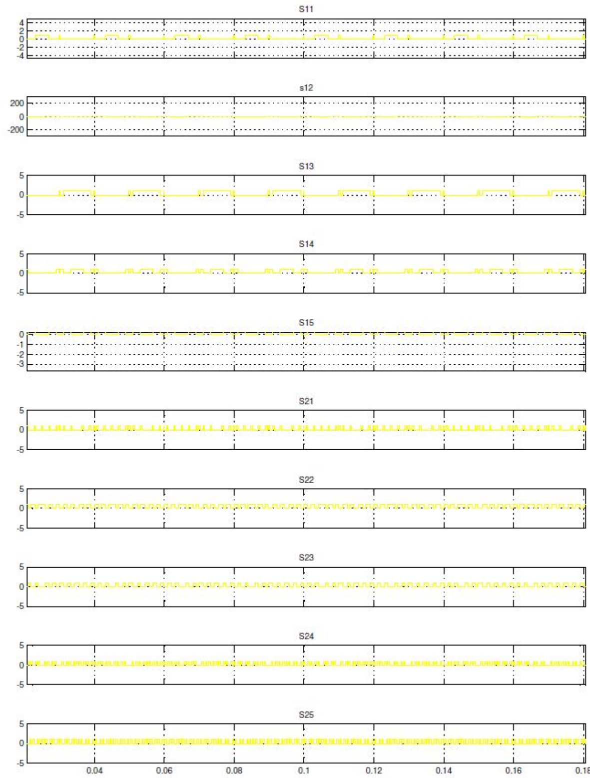

Figure 13: Output voltage of first and second basic cells

IV. CONCLUSION

In this paper, a cascaded multilevel inverter is proposed which requires minimum number of switches with increased output levels where, output waveform is near-sinusoidal. Compared with conventional multilevel inverters, it requires less number of components to achieve same number of output levels. Overall total harmonic distortion (THD) is very low and thus the quality of output waveform is improved. Also this asymmetric multilevel inverter is more advantageous over symmetric multilevel inverter using same number of switches, for producing more number of output levels. Due to the use of fewer switches, optimized circuit layout and packaging is possible. Thus less cost is required to implement the proposed inverter. When sinusoidal pulse width modulation (SPWM) technique is installed THD value will reduce even further. This topology can be successfully installed for solar based ac applications.

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