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Modeling, Simulation and Analysis of Dual Cell Three Phase Multilevel Inverter Having Low THD

Mohd Tariq[1*] --- Md. Isharat Khan[2] --- Yogendra Kumar[3]

[1] Ex Faculty, Department of Electrical Engineering, Maulana Azad National Institute of Technology, Bhopal, India.
[2] Faculty, Department of Electrical Engineering, Maulana Azad National Institute of Technology, Bhopal, India.
[3] Professor & HoD, Department of Electrical Engineering, Maulana Azad National Institute of Technology, Bhopal, India

Abstract

Recent advances and development in power electronics and control technologies have made the multilevel concept practical. Much research has been done on the advanced control and modulation algorithm for increasing the level of inverter output and decreasing Total Harmonic Distortion (THD). In this paper Dual Cell three phase seven level inverter has been investigated, modeled and analyzed. Digital simulation has been performed on MATLAB Simulink platform in SimPower System blockset to verify the model and analysis. The results obtained are discussed and shown that the THD of the system is coming 3.12% for voltage and 1.96 % for current (a very low THD and under the limit given by IEEE standards).

Keywords: Dual cell, Multi level inverter, THD, MATLAB/ Simulink.

Contents

* *Corresponding Author*

1. Introduction

Multilevel inverters are widely used in power industry and renewable energy industry nowadays. Multilevel means level more than three. Recently researches related to Multi-level inverters are of much interest to researchers, reason being its high application in power and renewable energy [1-3]. Merits of Multi level inverter are better harmonic performance, good power rating, and less EMI emission. Some of the most common multi-level topologies known are Cascade, Diode-clamped, and flying capacitor. For switching of the switches involved in these topologies, many modulation strategies have been already done and reported in the literature. Among the reported literature the Carrier-based method and Space Vector Modulation (SVM) method are the most sought and most popular ones [4-8]. Application of multilevel inverters is now in every field. In power system and transmission area, active control of reactive power (var) is essential to stabilize the frequency and to stabilize the supply voltage. In DC transmission application of multilevel inverter is very important as it helps in reducing harmonics [9, 10].

In renewable energy, application of Power electronic converters is developed to integrate the photovoltaic (PV) arrays and utility grid. Inverters are needed to convert the DC electricity produced by the PV array into AC electricity required for loads. Multilevel inverter gained so much popularity in photovoltaic systems as multilevel inverter has a lot of advantages over conventional inverter which includes better harmonics since multilevel inverter generate nearly sinusoidal output voltage waveforms and the total harmonic distortion (THD) is also low [11-17].

Fig 1 shows Dual cell three phase multilevel inverter. As can be seen from the figure that 12 switches are used in this topology. Two separate DC sources are also used of the same value. Two capacitor of same value are used. Presently dual cell multilevel inverter is a very interested topic for researcher owing to its advantages like less THD, high power rating etc.

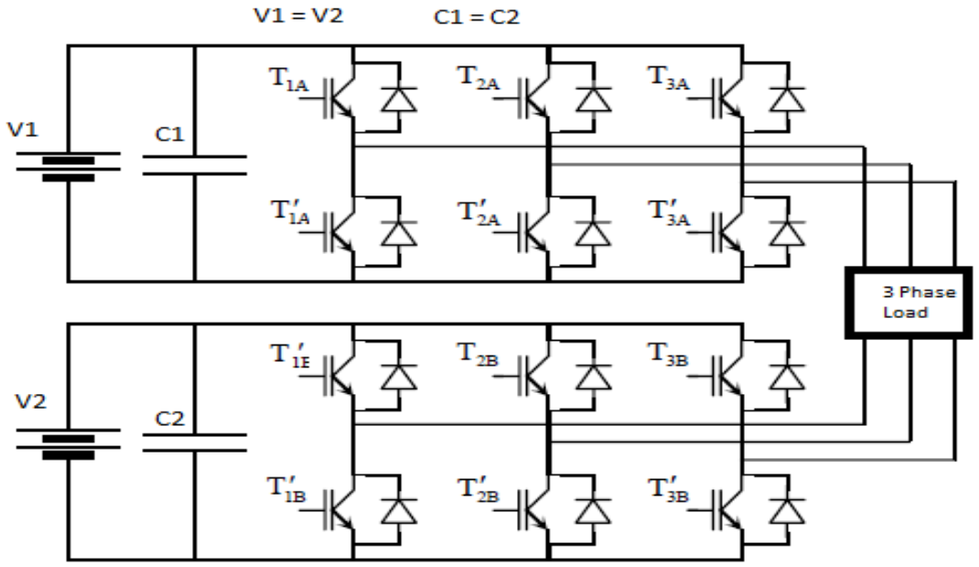

Fig-1. Dual Cell Three Phase Multi Level Inverter

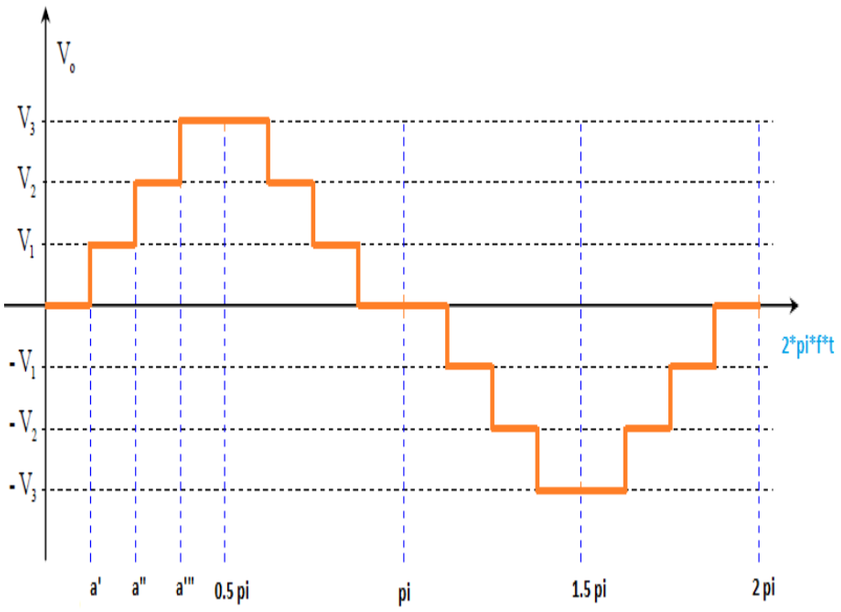

Fig-2. Output waveform of a 7-level converter

Fig 2 shows output waveform of a 7 level converter/ inverter. As can be seen from the figure the waveform is more symmetrical to sinusoidal waveform. Hence it will be having very less THD.

In this paper modeling and simulation of multilevel dual cell inverter has been performed in SimPower System blockset of MATLAB Simulink. Section II gives the detail regarding modeling of the topology. Section III discusses about the simulation. Section IV presents results and discussion.

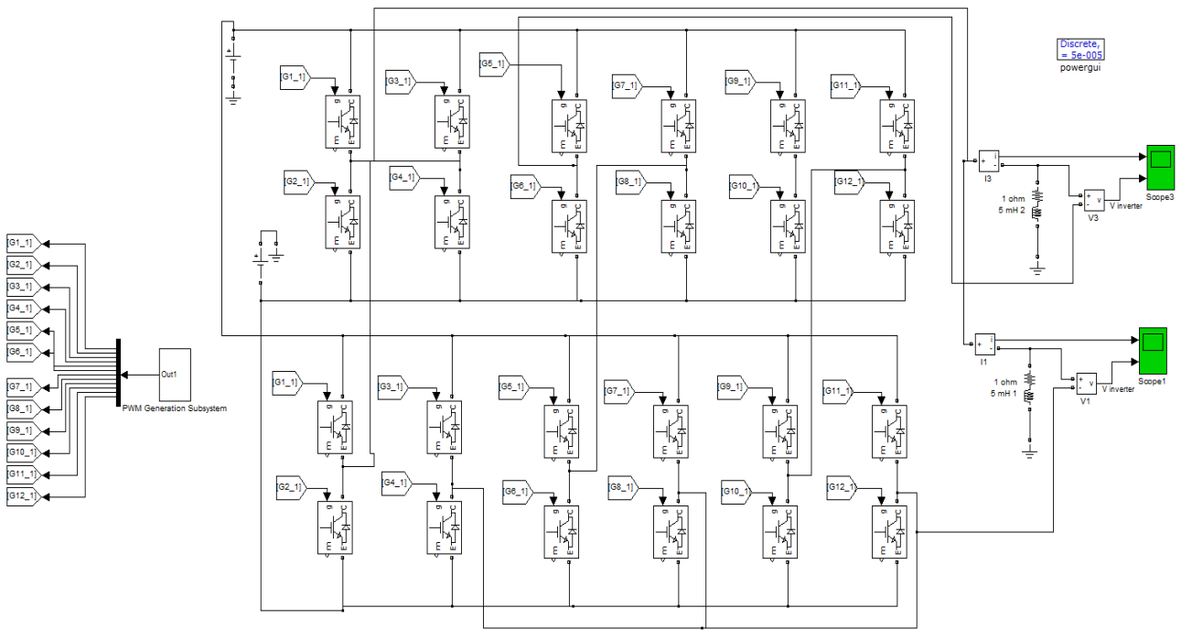

Fig-3. Simulink model of Dual Cell Series Cascaded 7 Level Inverter.

2. Modeling

The investigated dual cell 3 phase 7 level multilevel inverter has been modeled in MATLAB Simulink. The model is shown in figure 3. In the model, 24 switches are used. 8 switches are there in one phase and hence 3 phase has 24 switches. Special PWM generation scheme has been used for generation of switching signals for all these 24 switches.

As can be seen in the model the switching pulses for up cell and lower cell are same. In effect one has to generate only 12 switching signals. For phase A, 4 switches are in upper cell and 4 switches are in lower cell. Special PWM generation block generates 4 switching signals for these 4 switches. The 1st switch in 1st leg of upper cell has same PWM signals as the 1st switch in 1st leg of lower cell.

Figure 3 clearly shows that two loads has been placed, one for upper cell and another for lower cell. Upper cell output will be two levels having high total harmonic distortion. Whereas lower cell will have less total harmonic distortion as the output is seven levels.

Total harmonic distortion which is a measurement of the harmonic distortion is generally defined as the ratio of the sum of the powers of all the harmonic components to power of fundamental frequency.

Total harmonic Distortion is used to characterize the linearity of a system of electric power systems and also its resemblance with the sinusoidal waveform. As per IEEE standard of Total Harmonic Distortion limits, total harmonic current distortion must be less than 5% of the fundamental frequency current at the rated inverter output. In the next section he Total Harmonic Distortion for simulated model will be shown and will be discussed also.

3. Results and Discussion

The results of the model are shown here and discussion is made here, figure 4 shows the output voltage of dual cell inverter. As can be seen from the figure it has seven levels. The Values are 200, 120, 80, 0, -80, -120, -200 V.

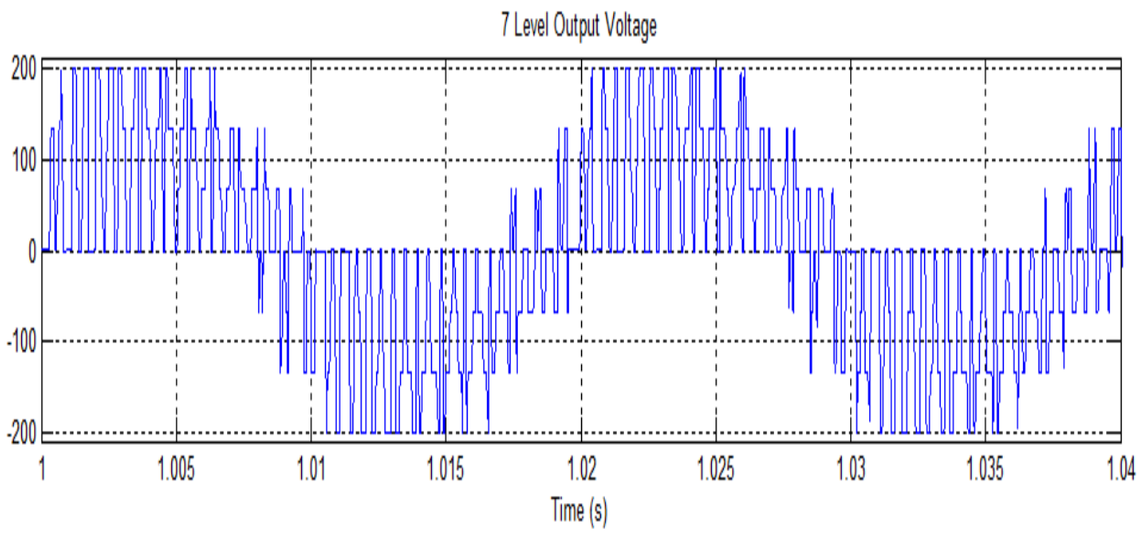

Fig-4. Output Voltage of Dual Cell Series Cascaded 7 Level Inverter.

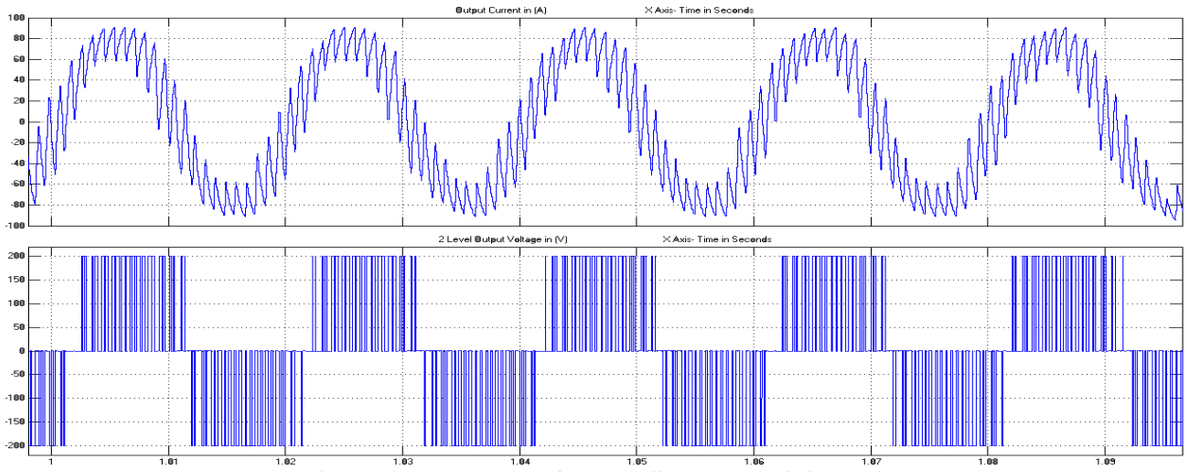

Fig-5. Voltage and Current Output of Upper Cell Series Cascaded 2 Level Inverter.

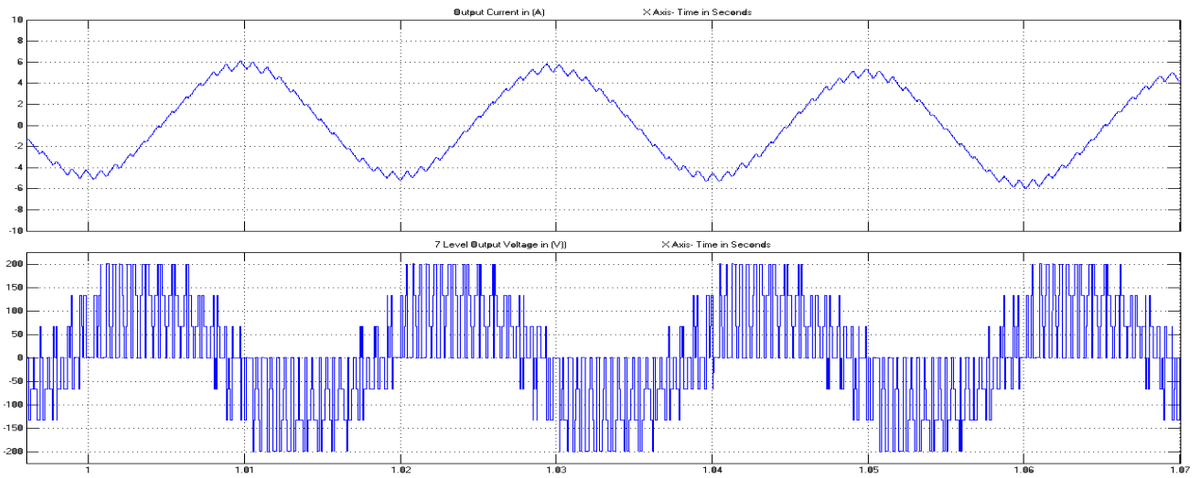

Fig-6. Voltage and Current Output of Lower Cell Series Cascaded 7 Level Inverter.

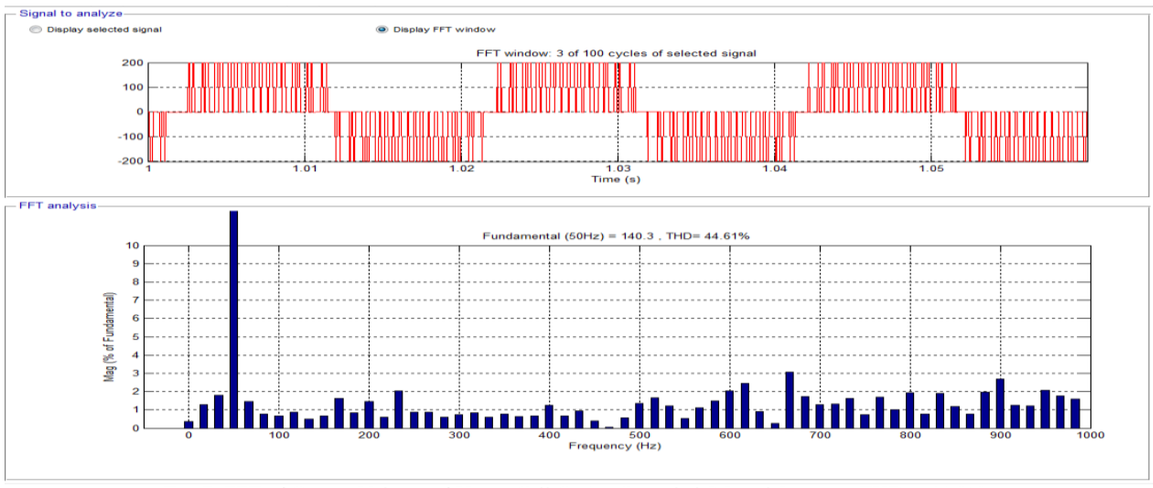

Fig-7. FFT of Output Voltage of Upper Cell Series Cascaded 2 Level Inverter, THD = 44.61%

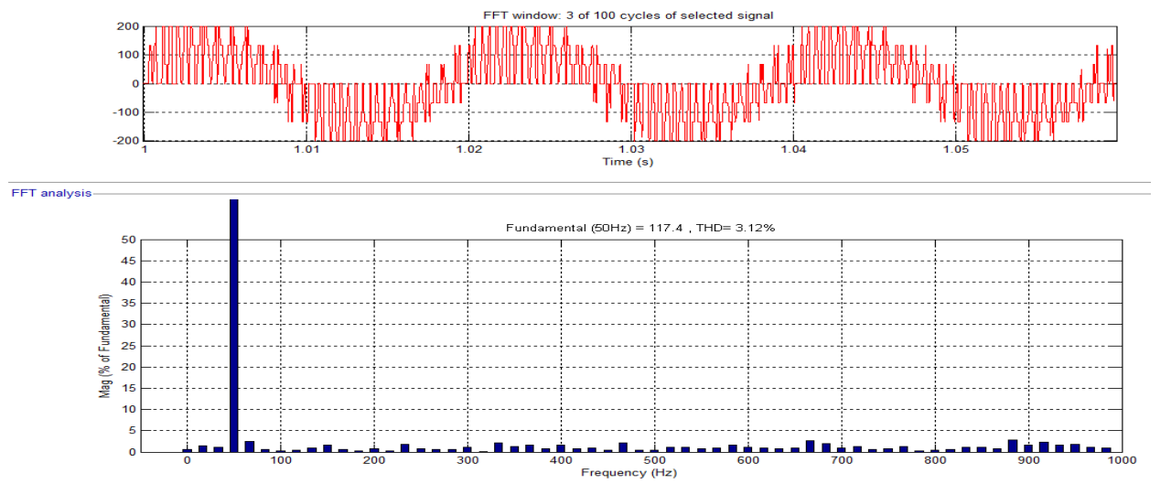

Fig-8. FFT of Output Voltage of Lower Cell Series Cascaded 7 Level Inverter, THD = 3.12%

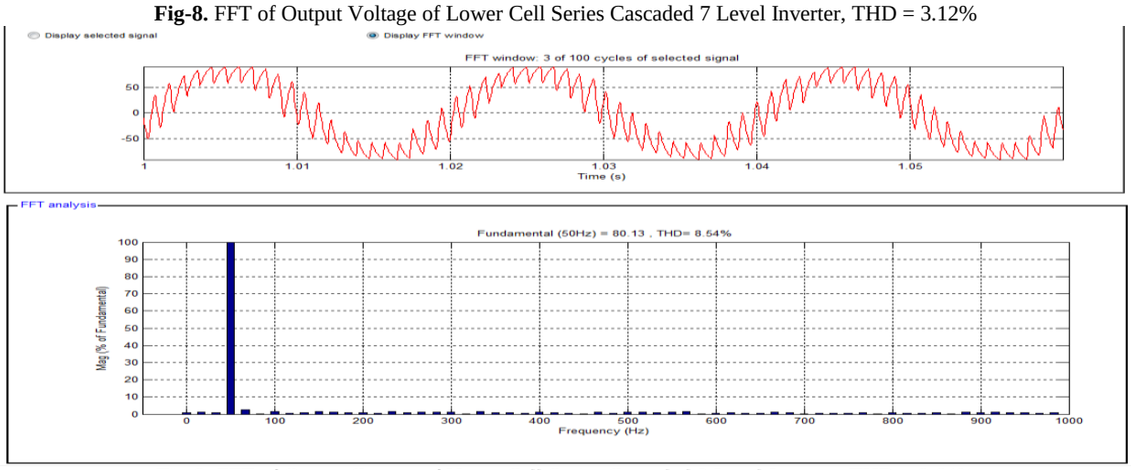

Fig-9. FFT of Output Current of Upper Cell Series Cascaded 2 Level Inverter, THD = 8.64%

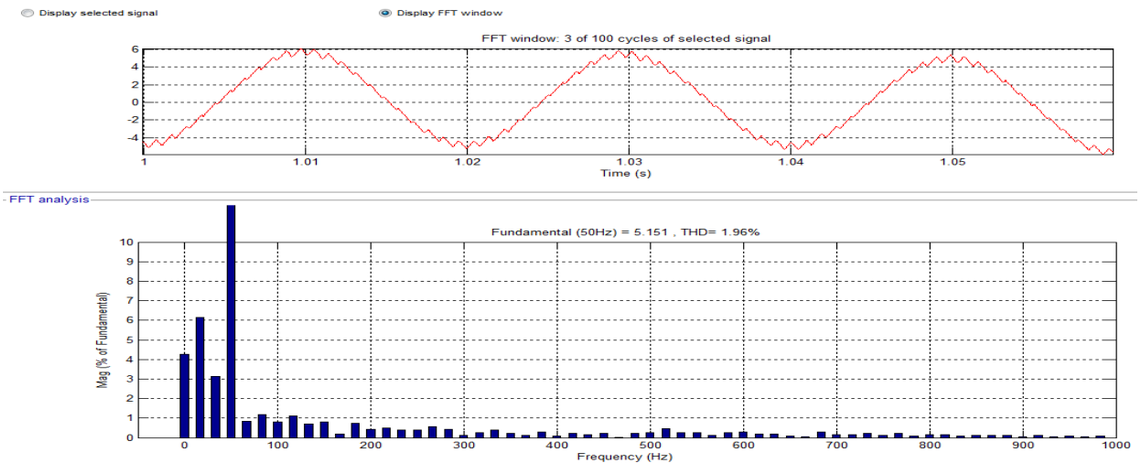

Fig-10. FFT of Output Current of Lower Cell Series Cascaded 7 Level Inverter, THD = 1.96%

Figure 5 shows the Voltage and Current Output of Upper Cell Series Cascaded 2 Level Inverter. As can be seen from the figure it has two levels of 200 and -200. The harmonics in current waveform can be seen from the figure very clearly. The output current is 80 amperes. Figure 6 shows the Voltage and Current Output of lower Cell Series Cascaded 7 Level Inverter. As can be seen from the figure it has seven levels of 200, 120, 80,0, -80,-120, -200. The output current is 6 amperes for dual cell as the load has been increased in this case. The waveform for both current and voltage are more near to sinusoidal waveform.

Figure 7 shows FFT of Output Voltage of Upper Cell Series Cascaded 2 Level Inverter. It clearly shows the THD = 44.61%, for two level inverter. Figure 8 shows that on increasing the level of inverter to seven, its THD reduces to 3.12 %. The reduction in THD is so prominent that it is very clearly visible from the waveform itself. Figure 8 waveform is almost sinusoidal in its nature whereas figure 7 is square in its nature. By comparing these two figures one can very easily understand the advantages of multilevel inverter.

Figure 9 and figure 10 shows the FFT of output current of two level and seven level inverter. THD of 2 level inverter output current is 8.64%, whereas THD of 7 level inverter output current is 1.96%. Hence the output current as well as output voltage of seven level inverter is much below the standards given by IEEE which is below 5%.

Table 1 shows THD for different levels of the investigated inverter. The table clearly shows that reduction in THD in voltage was 1430 %. Whereas the reduction in THD in current was 441 %.

Table-1. THD results for different levels

Total No. of Level	THD
2 Level Voltage	44.61%
2 Level Current	8.64%
7 Level Voltage	3.12%
7 Level Current	1.96%

4. Conclusion

This paper has investigated a dual cell series cascaded 7 level inverter. The results shown and discussed above are of prominent importance as it shows that the harmonic can be reduced to less than 2% THD. The paper was also successful in showing the waveforms pertaining to 2 level and 7 level very clearly so that the advantages of multilevel can be understood very easily. On seeing and observing these waveform, one will very easily say that multilevel has very less THD as the waveform resembles more symmetry to sinusoidal wave. These results are very interesting and are very important for industry, especially for the application of power electronic converter in the area of transmission (FACTS etc.), renewable energy (integration of PV cell with the grid). Future study can be made for the integration of this dual cell 7 level inverter with PV cell and a combine investigation of MPPT and THD can be analyzed.

5. Acknowledgements

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