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A New Single Phase 5- Level Inverter Fed from Hybrid Renewable Energy System with Less Number of Switches

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Abstract*: Renewable energy sources such as photovoltaic, wind, and low-head hydro and geothermal are expected to increase greatly their market share of the total power produced in the world. Fuel cell technology is also nearing the development point where it could start to supply a significant share of the power needs. For high-voltage electrical systems multilevel inverters have been developed to overcome shortcomings in the ratings of solid-state switching devices. The distinct structure of multilevel voltage source inverters permits them to get high voltages with less harmonic content and transformer less operation. This forms these distinct power electronics topologies suitable for custom power and flexible ac transmission systems (FACTS) applications. The use of a multilevel converter to control the real and reactive power flow at a dc/ac interface, frequency, voltage output (including phase angle), provides significant opportunities in the control of distributed power systems. In this paper new system architecture for hybrid photovoltaic and wind energy system connected to the grid. Depending on their availability this method permits these renewable energy sources to deliver the load together or independently. This proposed five level multilevel inverter uses less switches when compared with the conventional Multilevel Inverter.
Keywords*: Renewable energy, multilevel inverter, Distributed generation, FACTS, THD.

I. INTRODUCTION

The increasing energy demand, increasing costs and exhaustible nature of fossil fuels, and global environment pollution have generated huge interest in renewable energy resources. Other than hydroelectric power, wind and solar are the most useful energy sources to satisfy our power requirements. Wind energy is capable of producing huge amounts of power, but its availability can't be predicted. Solar power is available during the whole day but the solar irradiance levels change because of the changes in the sun's intensity and shadows caused by many reasons. Generally solar and wind powers are complementary in nature. Therefore the hybrid photovoltaic and wind energy system has higher dependability to give steady power than each of them operating individually. Other benefit of the hybrid system is that the amount of the battery storage can be decreased as hybrid system is more reliable compared to their independent operation. A five level inverter is employed to change the dc voltage from battery to ac voltage and connect to the grid. Multilevel inverters synthesize a desired voltage from several levels of direct current voltages as inputs. With the increase in number of levels, the generated output waveform is staircase wave with more number of steps. Thus output voltage approaches the desired sinusoidal waveform. Main advantages of using multilevel inverter topology are reduction of power ratings of power devices and reduction in their cost.

The basic concept of a multilevel converter is to get higher operating voltage using a series connection of power semiconductor switches with much lower voltage rating compared to power switches used in conventional two-level inverter. These power switches are controlled such that more number of voltage levels is generated at the output using multiple dc sources. The attractive features of a multilevel inverter are that they can generate the output voltages with very low THD, can draw input current with low distortion, and can operate at wide range of switching frequencies from fundamental frequency to very high frequency. The common topologies for multilevel inverters are diode clamed, flying capacitor and cascaded H- bridge multilevel inverter. The Cascaded multilevel inverter synthesizes its output nearly sinusoidal voltage waveforms by combining many isolated voltage levels..

II. PROPOSED CONCEPT

The block diagram of the proposed architecture is shown in Fig. 1. By using hybrid energy sources we are delivering voltage to five level inverter.

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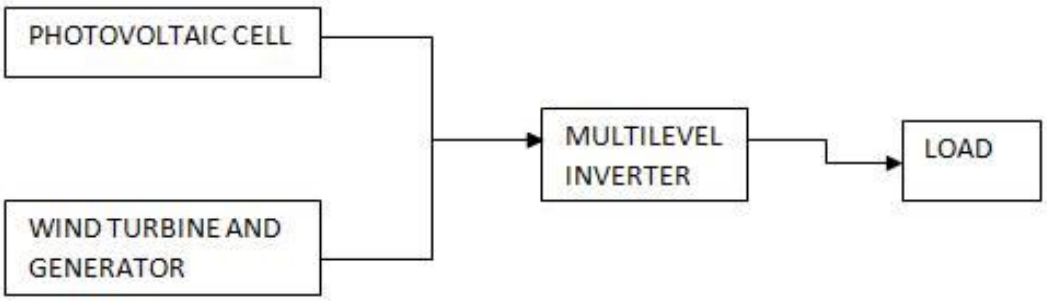

Fig 1. Block diagram of proposed architecture

Here, photovoltaic cell and wind turbine are two energy sources used. The output of these energy sources are connected to Multilevel Inverter. The output is five level inverter which is connected to the load.

The modified single phase five-level inverter uses a full bridge structure having an auxiliary circuit. The circuit diagram is shown in Fig.2

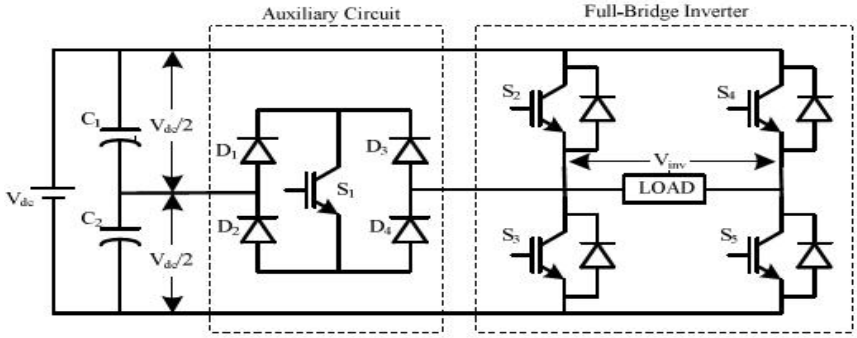

Fig 2. Circuit diagram of five level inverter

The voltage across each DC capacitor is $V_{dc}/2$. The working principle of the suggested inverter is to create five levels of output voltage, V_{dc}, $V_{dc}/2$, 0, - $V_{dc}/2$ and - V_{dc}. An auxiliary circuit consisting of four diodes and a switch is used for generating five voltage levels at the output. Using proper switching sequence in this modified circuit generates five levels in output voltage. Table 4.1 shows the switching sequence used for creating five levels for the output voltage.

Table 1: Switching sequence

S_1	S_2	S_3	S_4	S_5	V_{inv}
0	1	0	0	1	V_{dc}
1	0	0	0	1	$V_{dc}/2$
0	1	0	1	0	0
0	0	1	0	1	
1	0	0	1	0	$-V_{dc}/2$
0	0	1	1	0	$-V_{dc}$

The output voltage waveform of the ideal five level inverter is shown in Fig 3.

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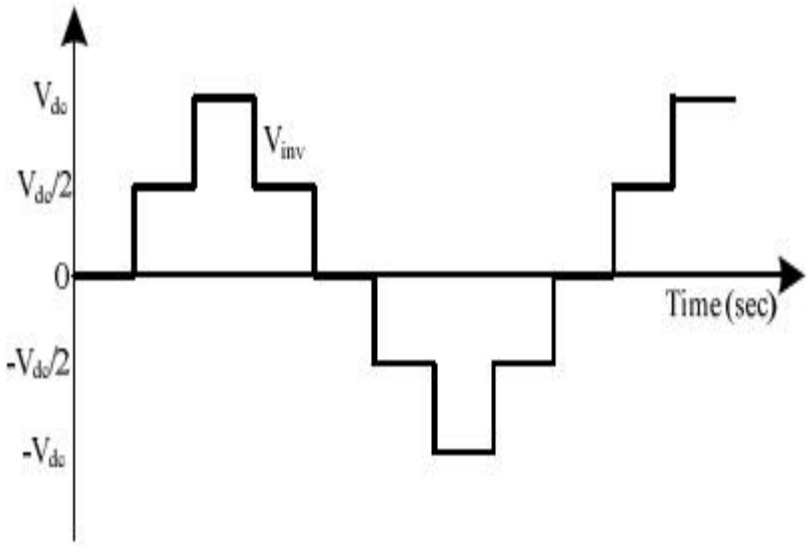

Figure 3. Ideal five level output voltage waveform

By increasing no of levels we can reduce total harmonic distortion. Increasing no of levels seems to near its sinusoidal waveform. In this waveform we can generate five voltage levels w.r.t to time on X-axis and Voltage on Y-axis.

A. Comparison of proposed and conventional multi level inverters

Level	Cascaded Multilevel Inverter	Proposed Multilevel Inverter
5-level	Voltage Sources:2 Switches:8	Voltage Sources:1 Switches:5
9-level	Voltage Sources:4 Switches:16	Voltage Sources:2 Switches:10

Table 2 comparison table

For cascaded 5 level Multilevel Inverter there are two voltage sources and eight switches. Coming to proposed Multilevel Inverter only one Voltage Source and five Switches.
For 9 level, four voltage sources are needed and 16 switches are required for 5 level. Next for proposed Multilevel Inverter two voltage Sources and ten Switches are required.

III.SIMULINK MODEL OF PROPOSED MULTILEVEL INVERTER

Here simulation is carried out with proposed multilevel inverter using less no of switches when compared with conventional multilevel inverter.

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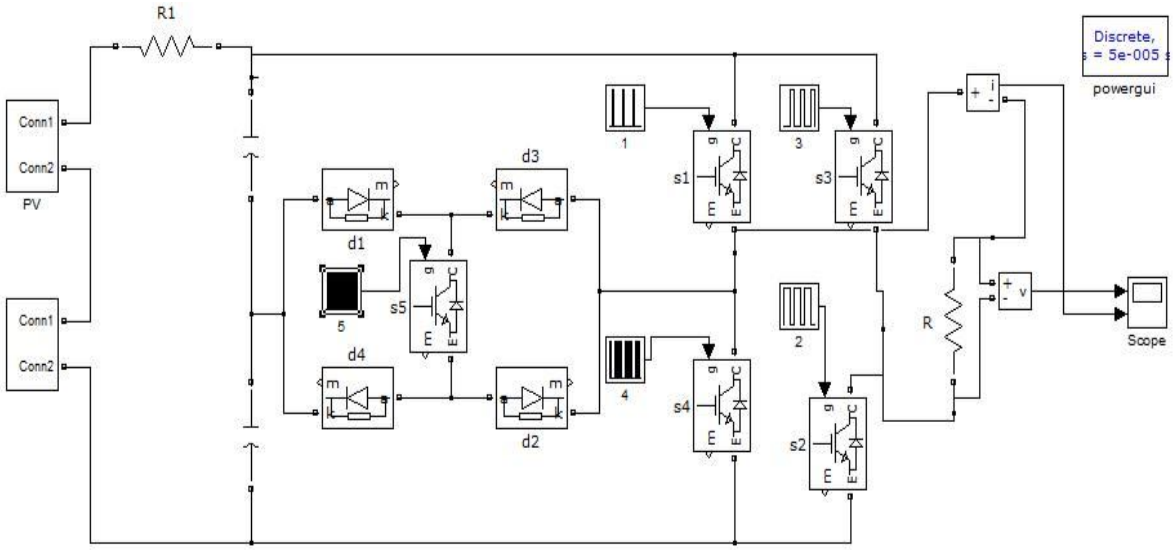

Fig 4 simulink model of proposed multilevel inverter.

This Simulink model provides 5 level inverter fed from hybrid energy sources. Here solar and wind energy sources are used. There are two subsystems pv cell and wind turbine and generator.
Now let us see subsystem of Photo Voltaic Cell. The simulink diagram is shown infig 5

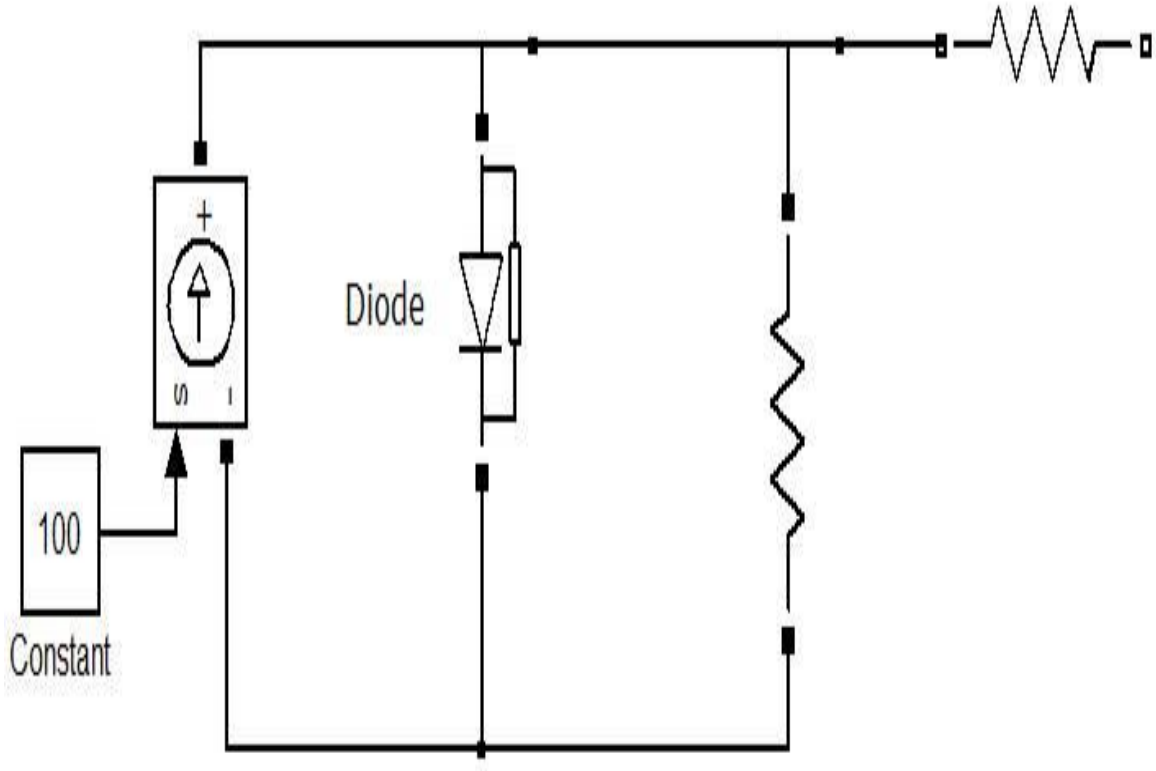

Fig 5 simulink model of photo voltaic cell

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The output waveform of photo voltaic cell is shown in fig 6. we can observe the waveform as a straight line as it is acts a DC source.

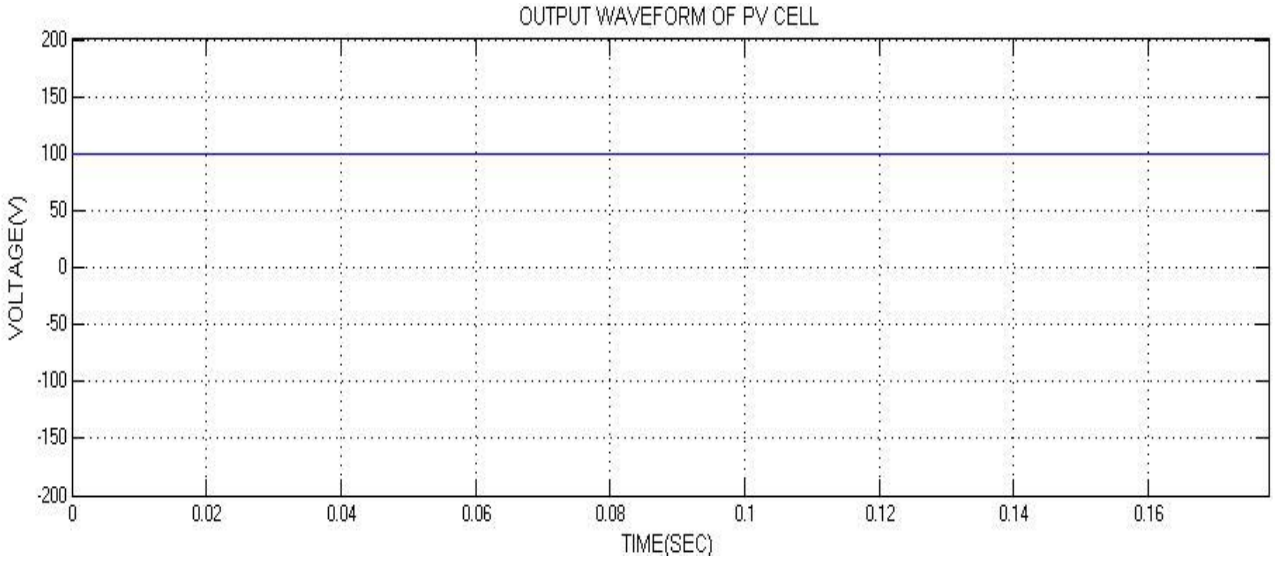

Fig 6: output waveform of pv cell

Now ,let us see another subsystem (wind turbine and generator).fig 7 shows the simulink model of wind turbine and generator.

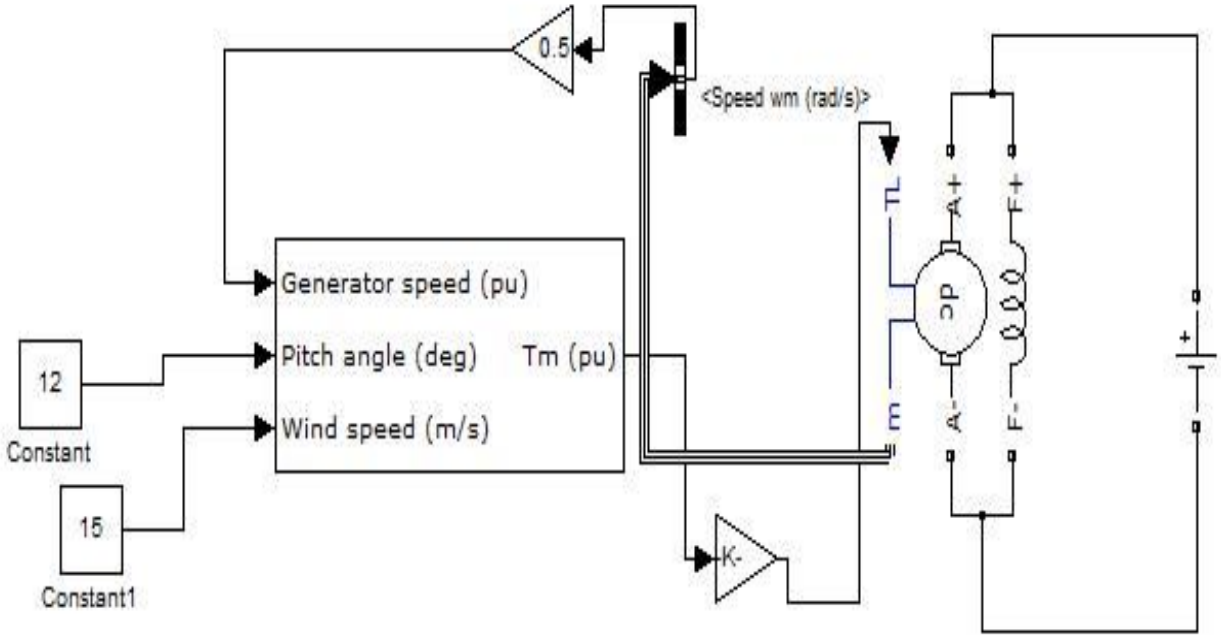

Fig 7: simulink model of wind turbine and generator

The simulink model of the wind turbine generator is shown in fig 7.wind turbine generates a torque which is used to drive the generator. The most commonly used generators are singly fed and doubly fed induction generators. They produce alternating voltage as output. But in our application we require DC output to charge the battery. Hence we used a permanent magnet dc generator. Now let us see the output waveform for this simulink model in fig 8.

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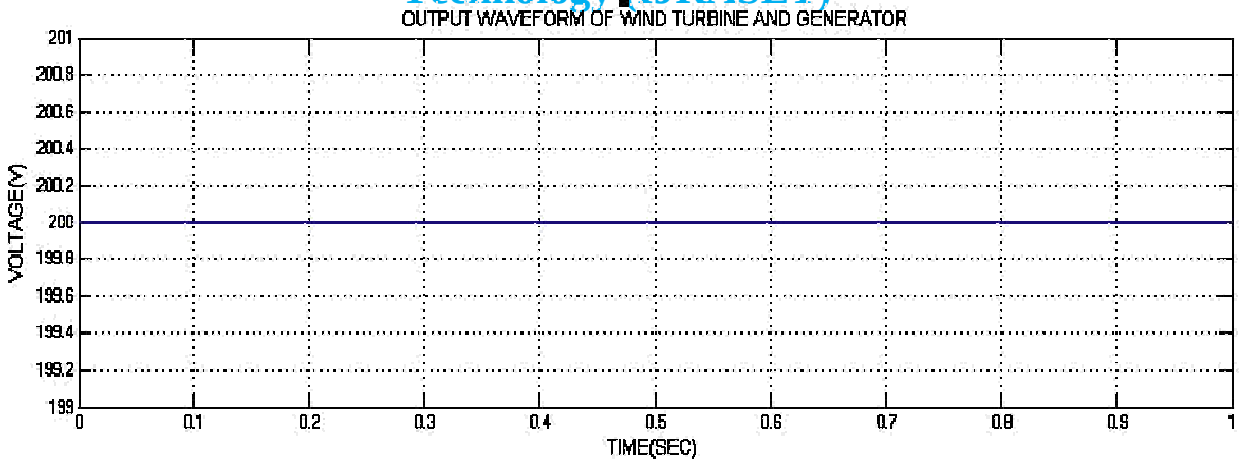

Fig 8: output waveform of wind turbine and generator

Now ,let us observe the output waveform of proposed multilevel inverter. i.e voltage and current waveforms in fig 9.

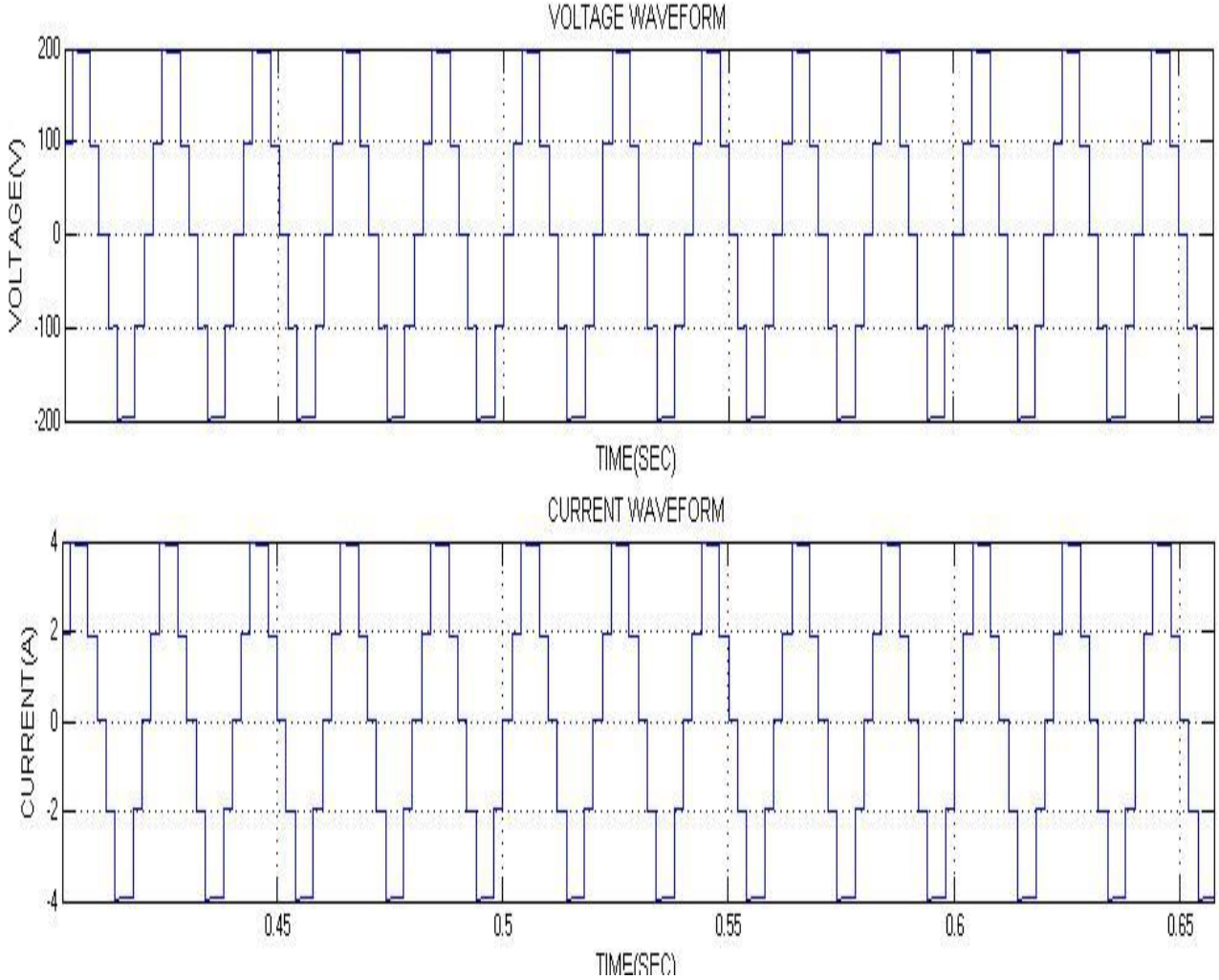

Fig 9: Output Waveforms of Proposed Multilevel Inverter.

The voltage waveform and current waveform are shown in fig 6.9. The X-axis represents Time(sec) and Y-axis represents

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Voltage(v).

A. Total Harmonic Distortion

The Total Harmonic Distortion of proposed Multilevel Inverter is 13.17%.

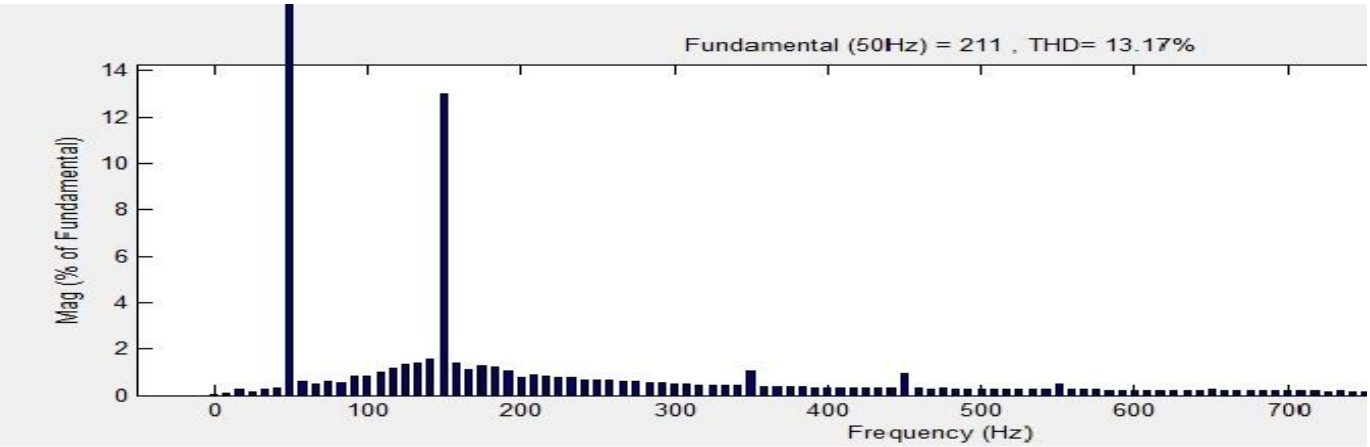

Fig 10

THD of Proposed Multilevel Inverter

Power Quality is based on THD. If the value of THD decreases then its quality increases. We can eliminate harmonics if THD is low. Switching losses decreases if THD is low.

B. THD Comparison Table

Inverter	Cascaded H-bridge Multilevel Inverter	Proposed Multilevel Inverter
THD Value	19.10%	13.17%

The THD value of cascaded H-bridge Multilevel inverter is 19.10% and for proposed Multilevel inverter its value is 13.17%. By using our proposed concept we can decrease its THD value it means harmonics decreases so ultimately power Quality gets increases. Switching losses decreases so its efficiency increases with less no of switches.

IV. CONCLUSION

From the simulation, it is noted that the new multilevel inverter topology works well and shows hope to reduce the complexity and initial cost. This is evident from the output waveforms of the cascaded and proposed multilevel topologies. When we increase the levels, the number of components i.e., switches and voltage sources are reduced when compared to the other topologies. The proposed system reduces THD and implements a hybrid energy system. Thus the proposed topology offers good flexibility in designing. This results in the lower stress on the power electronic devices and lower losses. Hence the switching loses reduces thus the overall efficiency of the system increases when we go for high levels.

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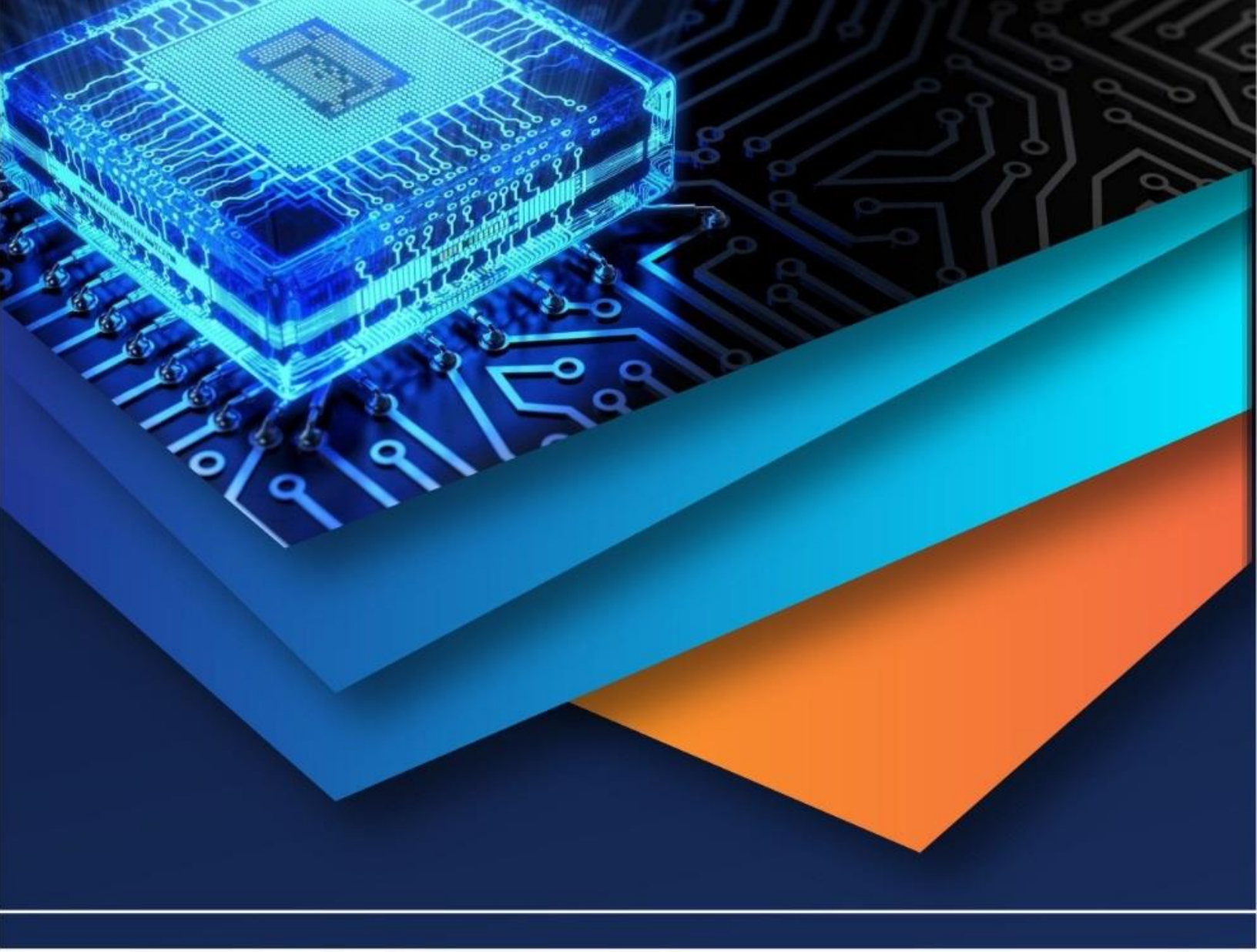

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